MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIII. APRIL 8, 1903. No. 6

Professor H. H. TURNER, D.Sc., F.R.S., PRESIDENT, in the Chair.

Thomas Frederick Bowers, B.A., Woolwich Polytechnic School, and Darenth, Little Heath, Old Charlton, S.E. ;
Frederick Hugh Capron, 38 Avenue Road, Highgate, N. ;
Lieut. Kenneth Essex Edgeworth, R.E., Stanhope Lines, Aldershot ;
Alphonso King, 93 Victoria Road East, Leicester ;
William Tillar, St. Hilda's, Westbourne Road, West Kirby, Cheshire ;
Gilbert Thomas Walker, M.A., Assistant Reporter in Meteorology to the Government of India ; and
Pollard Wilkinson, B.A., B.Sc., 21 Ashmere Grove, Ipswich,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as Fellow of the Society, the name of the proposer from personal knowledge being appended :—

Alfred Pratt, B.A., B.Sc., 14 Endwell Road, Brockley, S.E. (proposed by Thomas Lewis).

Sixty-three presents were announced as having been received since the last meeting, including amongst others :—

L. Brenner, Jupiter-Beobachtungen auf der Manora Sternwarte 1898–1901, presented by the author ; Breslau, Königliche

Sternwarte, Mittheilungen, II., presented by the Observatory; Brussels, Société belge d'Astronomie, Bulletin, Année 1–8, presented by the Society; Carte photographique du Ciel, 33 charts, presented by the French Government; Osborne Reynolds, The Sub-mechanics of the Universe, presented by the Royal Society; T. N. Thiele, Theory of Observations, presented by the author; Washburn Observatory Publications, vol. xi. (meridian observations for stellar parallax), presented by the Observatory; L. Weinek, Definitive Resultate aus den Prager Polhöhen-Messungen, presented by the Prague Observatory.

Preliminary Note on the Possible Existence of two Independent Stellar Systems. By F. A. Bellamy and H. H. Turner, D.Sc., F.R.S., Savilian Professor.

The authors desire to withdraw this paper. It was intimated in the January number of the *Monthly Notices* that some numerical corrections had been found necessary; but it was not possible to say at the time how far the main conclusions would be affected. On going carefully through the work it is found that the correction is unfortunately vital, and the trace of a double polarity which now remains is practically negligible

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Note on a New Star in the Constellation of Gemini.
By F. A. Bellamy.

The circumstances attending the discovery of a *Nova* are perhaps of sufficient general interest to warrant their being given in some detail. On the night of March 16 I was exposing plates in zone $+30°$ required to complete that zone for the Astrographic Survey, and among the few required was that with the coordinates of the centre of the plate equal to $6^h\ 36^m\ +30°$. Having some difficulty in identifying the star for which I had set the micrometer scales and instrument, owing to its faintness (8·6) in an illuminated field, I decided to use a bright star which I thought was in the same field of view and less than half a réseau interval away. I accordingly moved the scales and brought the bright star into bisection, and exposed the plate for 6^m, and also gave it 4^m and 20^s.

Whilst exposing the plate Mr. H. C. Plummer came into the Dome and asked if he could help. I remarked to him that I had

some trouble in picking up the star as given in the catalogue, and said I was using a bright star of the seventh magnitude—a magnitude distinctly visible in a bright field in the 12¼-inch O.G.—and had moved the scale to that star ; would he alter my setting in y in the note-book and write $+2'\ 40''$ instead of $+5'\ 0''$. I further said that I should finish the exposures, though I expected I should have to take the region again, as I believed there was some error in the catalogue star (B.D. $+30°$, 1306), as neither the setting nor the magnitude agreed with the bright star I used ; and I could not then think why an 8·6 star had been selected when there was a seventh-magnitude star so near it, and suspected a transposition of figures intended for 6·8 mag. I developed the plate (No. 2193) the next day and examined it the following day, when we found that I had erroneously set the telescope by 1^m in hour-angle, and so used another star. This being beyond the limits of error in setting permissible, the plate was rejected without further examination and put among the rejected plates in the lecture room, and the region marked to be taken again.

On March 24 Professor Turner was going through all the plates recently taken. I may say that we had had a batch of plates which were not quite so rapid as usual, and this, with some indifferent weather, put a number of plates on the border line between acceptance and rejection. After settling which were to be rejected Professor Turner took them to the lecture room, and in putting them with others found three plates apparently rejected by mistake, as no reason was written on the envelope. He took them upstairs for inquiry and was told that No. 2193 had been rejected for wrong setting, though the notification of this fact had been accidentally omitted. To guard against a repetition of the error in setting, he took down an "overlapping" plate from the rack, viz. Plate 963, Centre $+29°\ 6^h\ 40^m$, exposed 1896 January 28, and saw at once that there was a strange object on Plate 2193, which had been used as a guiding star and accounted for the wrong setting. The following plates were also examined and no trace of this object found :—

Plate.	Centre.			Exposed.
	°	h	m	
1903	+30	6	36	1902 Mar. 3
2126	„	„		1903 Feb. 21
2154	+31	6	40	1903 Feb. 28

Chandler's third catalogue of variable stars was consulted without result, and subsequent lists of new variables as given in the *Astronomical Journal*. The distances between the three images on Plate 2193 were measured and compared with those of stars with which they were found to agree, so that there was evidence against the strange object being a planet. Professor Turner measured its position on Plate 2193 by use of four com-

parison stars (Leiden 2763, 2803, 2782, 2786) on the afternoon of March 24, and found the following place for 1900·0:

$$\text{R.A.} = 6^h\ 37^m\ 48^s{\cdot}86 \qquad \delta = +30^\circ\ 2'\ 39''$$

After sunset the clouds cleared, and on setting carefully for the plate centre $6^h\ 36^m + 30^\circ$ by means of the adopted guiding star, Cambridge 3447 or B.D. + 30° 1306, he saw the strange object at once. He exposed a plate (No. 2205), and after securing the exposure measured the distance of the object from the guiding star in R.A. by transit in Decl. by the scale for "setting." The differences were found to agree closely with those found by measurement on Plate 2193 during the afternoon.

As it seemed by this time probable that the object was a *Nova*, post-cards were sent off at once to several spectroscopic observers; and early the next morning a telegram despatched to Kiel.

Positions of the Nova and Surrounding Stars.

It was considered advisable to measure the position of the new star, and also as many stars as were visible on the plate within a radius of about three réseau intervals (15′), to assist others in measuring or examining photographs of this region already taken, or for use in visual work with a telescope.

I have accordingly measured all these stars on Plate 2205, only twelve in number, and probably none fainter than about the tenth magnitude; also forty-nine stars, which appear in the Cambridge and Leiden A.G.C.s, used for the determination of the constants for the plate. It is not necessary to give the measures of the latter—I measured them in the direct and reversed positions and took the mean—nor the equations which give for the final constants.

Plate 2205, 1903 March 24, Sid. Time of Exposure $8^h\ 41^m\ 35^s$

a	*b*	*c*	*d*	*e*	*f*
−·00024	+·00567	−·1416	−·00563	−·00051	−·1625

As a check on the work the residuals were formed for each of the forty-nine stars, but these need not be given.

The third exposure, being 4^m, was measured, as it showed the most satisfactory images; the night was not fine.

The uncorrected measures of the *Nova* are $\overset{x}{17}{\cdot}6455$, $\overset{y}{13}{\cdot}2695$. The Oxford coordinates, ξ' and η', and the corresponding R.A.s and Decs. for the *Nova*, these twelve stars, and for Camb. 3447, 3455, and 3467 will be found included in Table I. It should be stated here that the position of the *Nova* for epoch 1900·0 derived from this plate (2205) is

R.A.	N. Dec.
$6^h\ 37^m\ 48^s{\cdot}96$	$30^\circ\ 2'\ 38''{\cdot}9$

TABLE I.

Places of Stars near the Nova, as found from Plate 2205; *R.A.* $6^h\ 36^m + 30°$. *Exposed* 1903 *March* 24.

	B.D.	Oxford Magnitude. Measured Diameter.	Equivalent Magnitude.	ξ'. 1900·0.	η'. 1900·0.	Deduced. R.A. 1900·0. h m s	N. Dec. 1900·0. ° ′ ″
1	+30° 1306, 8·6	18·5	8·3	14·3590	13·9982	6 36 31·40	30 4 59·2
2		9·5	10·2	14·7767	17·0656	6 36 41·19	30 20 19·2
3		10·5	10·1	14·8166	13·2831	6 36 41·96	30 1 24·5
4		16·0	9·6	16·1796	13·7041	6 37 13·47	30 3 30·0
5		11·0	10·1	16·6737	13·3785	6 37 24·86	30 1 51·6
6	+29 1324, 9·5	9·0	10·3	16·7068	10·8945	6 37 25·45	29 49 26·6
7		9·0	10·3	16·8126	12·4133	6 37 28·00	29 57 2·2
8		8·5	10·3	17·2151	11·5471	6 37 37·23	29 52 41·9
Nova		30	8·16	17·7160	13·5390	6 37 48·96	30 2 38·9
9		8·5	10·3	17·9231	11·2601	6 37 53·53	29 51 15·3
10		9·5	10·2	19·3946	14·5225	6 38 27·86	30 7 31·6
11		11·5	10·0	19·3956	14·4961	6 38 27·88	30 7 23·4
12		9·5	10·2	19·4201	12·5416	6 38 28·21	29 57 37·3
13		13·0	9 9	19·8411	12·4594	6 38 37·91	29 57 11·9
14	+30 1316, 9·0	18·0	9·4	19·8365	15·3755	6 38 38·18	30 11 46·7
15		16·0	9·6	20·0256	11·2296	6 38 42·00	29 51 2·7

The earlier plate, 2193, would have given nearly twice as many stars within 15′ of the *Nova*, but time has not allowed of its measurement and reduction in the midst of other pressing work.

The Magnitudes from the Measured Diameters.

To determine the magnitudes the formula used was that obtained, provisionally, from a large number of plates by Professor Turner.

$$\text{Diameter} = 13(10{\cdot}8 - \text{magnitude}) + x(12{\cdot}3 - \text{mag.}) \times 0{\cdot}3$$

x being a constant to be determined from each plate and exposure, the magnitudes being those of Argelander. Since (12·3 − mag.) × 0·3 is approximately unity for the mean of the stars on the plate, x is found from the mean excess of diameter over the first term.

For Plate 2193 (March 16) x, from forty stars ranging from 6·0 to 9·5, came out to be −4·4, the resulting magnitude of the *Nova* being

6·93 from the first exposure of 6 minutes.

x for the second exposure is $-7\cdot2$, the resulting magnitude being

6·69 from the second exposure of 4 minutes.

The third exposure is not shown for all stars.

Plate 2205, *exposed March* 24.

Similarly, for this plate x was determined to be $-8\cdot0$ for the third exposure ; the other two have not yet been measured.

The mean measured diameter of the *Nova* is 30·0 (unit = 0″·3), and the resulting magnitude obtained is

8·16 from the third exposure of 4 minutes.

In the same way the equivalent magnitudes in Table I. have been obtained.

Saturday, April 4.—From a careful comparison of the *Nova* with +30° 1306, 8·6, I estimated its magnitude to be 0·2 brighter, *i.e.* 8·4 ; the Moon was near. Two plates were also exposed.

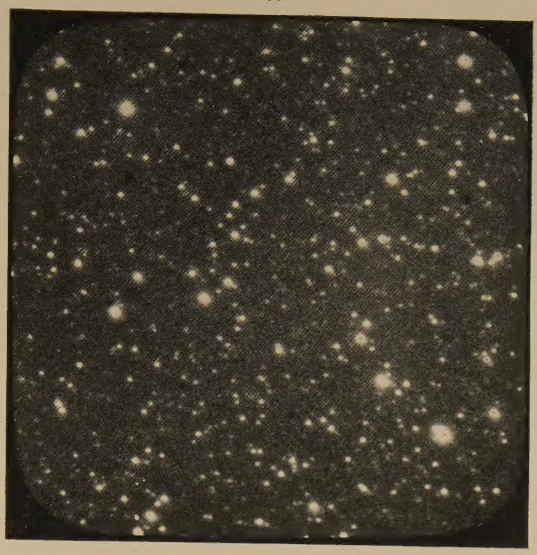
April 23.—In response to applications for positions of fainter stars than the 11th mag. within 15′ of the *Nova*, a plate is being measured which contains stars to the 14th or 15th mag., and the results will probably be communicated to the Society at the May meeting.

University Observatory, Oxford :
1903 *April* 4.

The Place of Nova Geminorum. By Max Wolf, Ph.D.

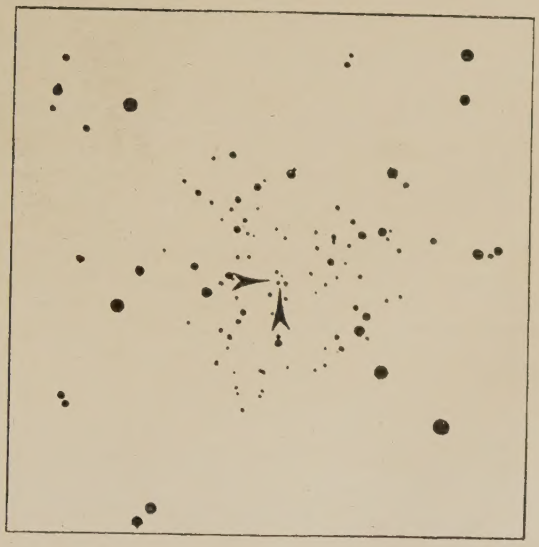
I send to the Society a direct enlargement of Dugan's plate of February 16 of the region of Nova *Geminorum*. I compared this plate under the stereo-comparator with a plate of Mr. Goetz of April 3. There is nothing exactly at the place of the Nova, but extremely near to it is a starlike object of about the sixteenth magnitude, and this extends over the place of the Nova, so that the Nova may be a part of this chain-like object. The original plate was exposed for three hours with my 6-inch Voigtländer lens. It is enlarged about five times. The exact place on the accompanying photograph (Plate 13) is shown on the key map by the intersection of the two lines near the centre.

Königstuhl : 1903 *April* 6.



REGION OF NOVA GEMINORUM.—MAX WOLF

1903 FEB. $16^{d}\ 9^{h}\ 3^{m}.1$ to $12^{h}\ 11^{m}.1$.



KEY MAP.

Rotation Periods of the Markings on Jupiter.

By W. F. Denning.

It seems desirable to trace, as closely as possible, the markings on *Jupiter* at successive oppositions, so that the changeable velocities of the different currents may be determined and compared. By this means it will ultimately become possible to ascertain whether the motions are subject to regular periodical variations in rate or whether they merely partake of the character of atmospheric vagaries, and are not reducible to any law. Long-continued observations of the markings may also furnish useful evidence as to their durations as visible objects, and also on the question of possibly recurrent outbreaks in certain latitudes after intervals of comparative quiescence.

As a contribution to a consecutive history of this planet's mobile phenomena, I have compiled the following summary of mean rotation periods computed from observations at Bristol, extending over the five years 1898 to 1902 inclusive, with a 10-inch Browning-With reflecting telescope and one of Steinheil's "monocentric micrometer oculars" of $\frac{1}{4}$-inch equivalent focus, giving a power of 312. Magnifiers of 252, 332, and 488 were occasionally employed, but the one of 312 was usually found the most serviceable and efficient.

During the five years named the planet was placed south of the equator (in 1900 and 1901 from $19\frac{1}{2}°$ to $23\frac{1}{2}°$ S.), and therefore in an unfavourable position for European observers. The suburb of Bishopston, from which my observations were made, lies due north of Bristol, so that the definition was sometimes much impaired by the situation of *Jupiter* immediately over the centre and amid the vapours of a populous city.

To what extent low altitude affected the telescopic images may be judged from the following figures. The planet was examined on 328 nights, and on 292 of these a note was made as to the quality of the seeing.

Definition very good	25	nights.
Good	52	,,
Fair	66	,,
Bad	93	,,
Very bad	56	,,

It would be premature to discuss the results fully, but it may be mentioned that during the five years the mean rotation periods of the markings varied as under :—

	h	m	s		h	m	s
Equatorial spots	9	50	$23\frac{1}{2}$	to	9	50	29
N. tropical spots	9	55	$26\frac{1}{2}$	to	9	55	$31\frac{1}{2}$
N. and N.N. temperate spots	9	55	50	to	9	55	$56\frac{1}{2}$
S. temperate spots	9	55	$18\frac{1}{2}$	to	9	55	$20\frac{1}{2}$
Great red spot	9	55	42	to	9	55	39

The great red spot, after exhibiting a retarded rate of velocity between 1878 ($9^h\ 55^m\ 33^s{\cdot}7$) and 1899 ($9^h\ 55^m\ 41^s{\cdot}9$), showed evident signs of acceleration in 1900. This became more strongly pronounced in 1901, during which year the object retained a stationary longitude (45°) relatively to System II. of Marth-Crommelin's ephemerides based on a period of $9^h\ 55^m\ 40^s{\cdot}63$. The acceleration further developed in 1902, and brought about a reduction in the rotation period of 3 seconds as compared with that in 1899, and the longitude of the spot on 1902 December 31 became 36°·3. This marking has presented an exceedingly faint, though somewhat variable, aspect in recent years, and its oval shape has only been discernible under the best conditions. For this reason satisfactory transits are not often obtainable, but a good substitute is found in the conspicuous hollow or bay on the S. side of the great S. equatorial belt, which has precisely the same longitude and rate of velocity as the red spot, and is undoubtedly very closely connected with that object.

It should be remarked that the differences in the rotation periods shown in the above table are the means derived from several objects in the same current. The individual objects exhibited larger discordances, for even at the same period the rate of motion of a current is very far from being equable throughout its circumference. To show how far this is the case it will be sufficient to give the extreme differences in rotation period observed in regard to the equatorial spots in four years :—

Summary of mean Rotation Periods of the Principal Mark-

Description of Markings.	Approximate Latitude.	1898. Rotation Period.	1898. No. of Spots.	1899. Rotation Period.	1899. No. of Spots.
	° °	h m s		h m s	
N.N. temperate spots	+40 to +25	9 55 50·1	2	9 55 29·8	1
N. temperate spots ...				9 55 53·5	1
N. tropical spots ...	+14	9 55 26·3	3	9 55 28·8	16
Equatorial spots S. side N. belt ...	+ 6	9 50 26·8	1	...	
Equatorial spots N. side S. belt ...	− 5	9 50 23·6	23	9 50 24·6	27
Great red spot ...	−20	9 55 41·8	1	9 55 41·9	1
S. temperate spots ...	−27 to −33	9 55 20·5	4	9 55 18·6	3
S.S. temperate spots ...	−35 to −40	9 55 14·0 (2) / 9 55 8·6 (2)		9 55 9·2	2

Date of observations ...	Mar.–July	June–Sept.
Nights of observation ...	51	76
Transits recorded ...	280	668

	Spot with Minimum Period. h m s	Spot with Maximum Period. h m s	Difference. sec.
1898	9 50 16·9	9 50 33·2	16·3
1899	9 50 18·0	9 50 35·0	17·0
1901	9 50 25·1	9 50 35·0	9·9
1902	9 50 24·4	9 50 29·1	4·7

From these figures it would appear that the velocity of the equatorial current displayed a more even rate generally in 1902 than in 1898 and 1899.

During the last few years I have frequently looked for a return of the rapidly moving spots observed in the N. temperate belt of *Jupiter* in 1880 and 1891, but have not certainly succeeded in recovering them. Both in 1901 and 1902 the region of the planet in about N. latitude 25°–40° exhibited a very disturbed condition, and dark spots were abundant ; but as far as could be observed they were all controlled by a very slow rate of motion. Confused definition and periods of unfavourable weather, however, prevented some of these markings from being followed as satisfactorily as could have been wished. On 1902 November 18 I observed two well-defined dark spots (also seen by the Rev. T. E. R. Phillips at Croydon) in the N. temperate region, the f. one of which occupied same longitude as the centre of the red spot hollow. A week later—on November 25—the two spots were missing : they had either moved rapidly westwards or disappeared altogether ; but much unfavourable weather followed, and the objects alluded to were never seen again.

ings on Jupiter in the years 1898 *to* 1902 *inclusive.*

1900. Rotation Period. h m s	1900. No. of Spots.	1901. Rotation Period. h m s	1901. No. of Spots.	1902. Rotation Period. h m s	1902. No. of Spots.
...	...	9 55 50·2	6	9 55 56·5	9
9 55 30·0	17	9 55 31·6	1	9 55 29·8	10
...	...	...	...	9 50 28·5	1
9 50 24·1	18	9 50 29·1	28	9 50 26·7	24
9 55 41 7	1	9 55 40·9	1	9 55 39·0	1
...	...	9 55 19·7	1	9 55 18·7	7
...	...	...	...	...	...

1899 Dec.–1900 Mar.	May–Nov.	1902 June–1903 Jan
36	76	89
307	547	1005

Of the total number (2,807) of transits 1,855 were of equatorial spots, while 952 were of other markings. The spots immediately south of the equator are generally more abundant and conspicuous than those lying north of it.

Bishopston, Bristol:
1903 *March* 18.

On the Orbit of Σ 2525. By W. Bowyer.

(*Communicated by W. H. M. Christie.*)

This star is

B.D. +27°, No. 3391, R.A. $19^h\ 22^m\ 30^s$, N.P.D. 62° 52′ } 1900

Mags. 7·5 and 7·7 (Σ)

In vol. liii., *Monthly Notices*, 1892 November, Mr. Gore computed an orbit of this double star from the observations extending from 1828 to 1892, the period obtained being 138·5 years.

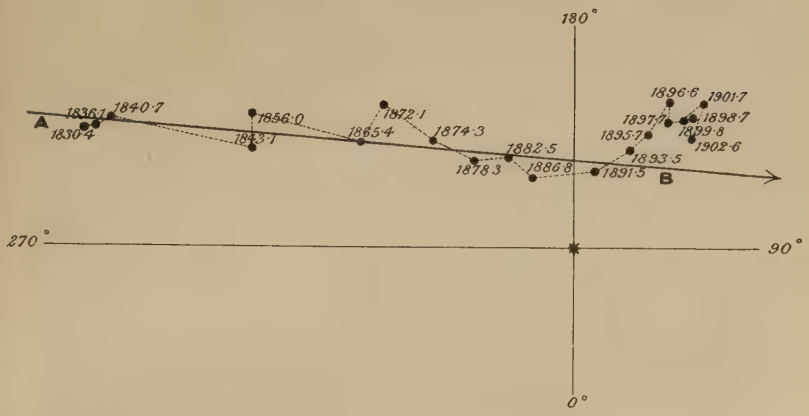
This orbit was merely intended to draw attention to the pair, for the material at Mr. Gore's command was really insufficient to discriminate between orbital and rectilinear motion, the observation of H. Struve in 1889 not being then published. The magnitudes of the components being so nearly equal, it was impossible to tell from the observations of 1886, 1891, 1892, whether the secondary star had swept through the two quadrants 180° to 0° and had reached the fourth quadrant in 1891·5, or whether it had simply continued its motion from A to B, as shown in fig. 1.

For the purposes of the present paper all available observations have been collected. The measures being in general somewhat discordant, it seemed advisable to group them, giving weights according to the number of nights. The mean places are shown in the following table. The abbreviations used are :—

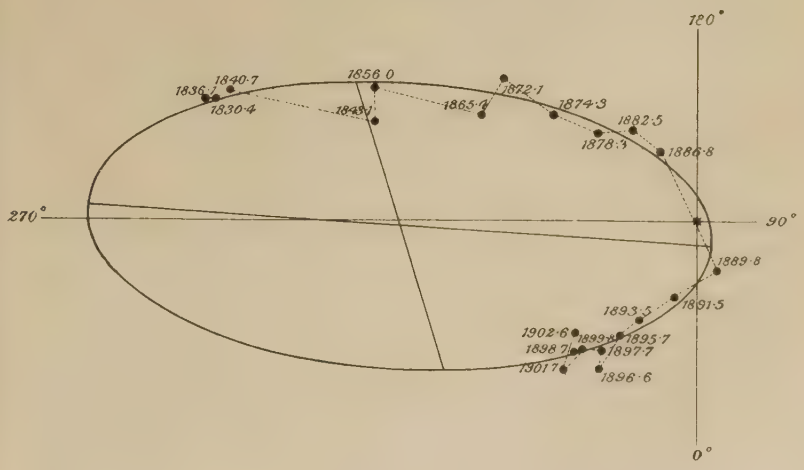
Σ, W. Struve ; OΣ, O. Struve ; HΣ, H. Struve ; Dem., Dembowski ; Schiap., Schiaparelli.

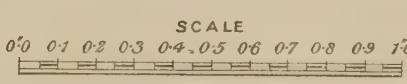
Date.	Position Angle.	Distance.	Observer and Number of Nights.
	°	″	
1830·43	255·9	1·33	Σ 5.
1836·14	255·5	1·30	Σ 2.
1840·67	253·5	1·27	Dawes 1, OΣ 2.
1843·06	252·5	0·89	Maedler 2.
1855·95	247·0	0·92	OΣ 1, Secchi 2.
1865·39	243·0	0·63	Dem. 7, OΣ 2, Engelmann 1, Secchi 1.

Σ 2525
FIG. 1.



Σ 2525 (Apparent Ellipse.)
FIG. 2.





Date.	Position Angle.	Distance.	Observer and Number of Nights.
1872·08	233°·6	0″·63	Dem. 1, OΣ 1.
1874·34	233·0	0·47	Wilson and Seabroke 9, Ferrari 1, Gledhill 1, Dem. 3, Schiap. 5.
1878·33	228·6	0·35	Schiap. 5, Dem. 1, Hall 3, Seabroke 2.
1882·52	215·8	0·29	Schiap. 10, Doberck 2, Engelmann 8, Perrine 4.
1886·80	210·0	0·22	Schiap. 2, Hall 1.
1887·71	single		Schiap. 1.
1888·78	single		HΣ 2.
1889·78	24·1	0·15 ±	HΣ 1.
1891·49	343·8	0·21	β 4, Hough 1, HΣ 1.
1893·46	329·3	0·30	β 1, Comstock 3.
1895·68	326·2	0·36	Dyson 1, Lewis 2, Glasenapp 2, Comstock 3.
1896·63	326·9	0·47	Lewis 4, Comstock 3.
1897·66	323·3	0·42	Lewis 5, Aitken 3.
1898·65	317·9	0·47	Lewis 3, Bryant 1.
1899·79	319·1	0·45	Aitken 3, Lewis 4, Bryant 3, Bowyer 3.
1901·65	318·1	0·52	Lewis 3, Bowyer 1.
1902·63	313·2	0·43	Lewis 1, Bowyer 3.

These means are plotted in fig. 1 (Plate 14) on the assumption that the motion is rectilinear; and it is evident that up to 1893 the measures are well satisfied by an annual motion of ″·024 along the line AB in the direction of 85°·5.

The following is an analysis of this motion :—

From 1830·4–1843·1 an annual motion of ″·030
1843·1–1856·0 „ „ „ „ ·025
1856·0–1872·1 „ „ „ „ ·021
1872·1–1882·5 „ „ „ „ ·019
1882·5–1891·5 „ „ „ „ ·027
1891·5–1902·6 „ „ „ „ ·014

The observations since 1893, however, cannot be thus satisfied. Moreover, the pair has been under constant observation at Greenwich, and although the difference of magnitude is but slight, observers are unanimous in placing the companion in the fourth quadrant.

In fig. 2 (Plate 14) the recent observations are plotted in the fourth quadrant and the apparent ellipse drawn. This also explains why in 1887 and 1888 no duplicity could be detected, and that

the measure of 1889 is in the first quadrant, as recorded by Hermann Struve. No doubt can then remain that the pair form a binary system.

An investigation of the apparent ellipse by Herschel's method yields the following elements of the true ellipse :—

$e = ·957$ $\quad a = 1''·41$
$\Omega = 25°\ 0'$ $\quad T = 1887·9$
$\gamma = 57°\ 4'$ $\quad P = 306·7$ years
$\lambda = 76°\ 23'$

The following table gives a comparison between the observed positions and the computed, using the above elements :—

Date.	Angle Observed.	Angle Computed.	θ O−C.	Dist. Observed.	Dist. Computed.	ρ O−C.
	°	°	°	″	″	″
1830·4	255·9	255·7	+ 0·2	1·33	1·30	+·03
36·1	255·5	254·2	+ 1·3	1·30	1·25	+·05
40·7	253·5	253·0	+ 0·5	1·27	1·20	+·07
43·1	252·5	252·5	0·0	0·89	1·16	−·27
56·0	247·0	249·2	− 2·2	0·92	1·05	−·13
65·4	243·0	244·4	− 1·4	0·63	0·86	−·23
72·1	233·6	240·4	− 6·8	0·63	0·71	−·08
74·3	233·0	238·7	− 5·7	0·47	0·66	−·19
78·3	228·6	234·5	− 5·9	0·35	0·54	−·19
82·5	215·8	227·4	−11·6	0·29	0·40	−·11
86·8	210·0	203·2	+ 6·8	0·22	0·14	+·08
87·7	single	135·7	...	...	0·05	...
88·8	single	14·6	...	...	0·12	...
89·8	241	359·4	+24·7	0·15 ±	0·17	−·02
91·5	343·8	346·6	− 2·8	0·21	0·23	−·02
93·5	329·3	335·3	− 6·0	0·30	0·30	·00
95·7	326·2	328·2	− 2·0	0·36	0·36	·00
96·6	326·9	325·9	+ 1·0	0·47	0·39	+·08
97·7	323·3	323·4	− 0·1	0·42	0·41	+·01
98·7	317·9	321·2	− 3·3	0·47	0·43	+·04
99·8	319·1	319·3	− 0·2	0·45	0·45	·00
1901·7	318·1	316·3	+ 1·8	0·52	0·49	+·03
02·6	313·2	315·1	− 1·9	0·43	0·50	−·07

The pair being now separated by 0″·5 is within the reach of most double-star observers, and should receive constant attention.

1903 *April* 4.

A Standard Scale for Telescopic Observation.

By Percival Lowell.

(*Communicated by the Secretaries.*)

Professor W. H. Pickering was quite right in calling attention to the origin of "A Standard Scale for Telescopic Observation." It was devised by him, although he modestly does not mention himself directly in the matter; and he deserves great credit for having devised it, as it is the only absolute scale—that is, the only one independent of the personal equation—which has yet been suggested. For large telescopes it needs to be compressed at the lower and expanded at the upper end, as it is a function of the aperture, and for exactness it must be supplemented by a record of the bodily motion as shown by Mr. A. E. Douglass: "Atmosphere, Telescope, and Observer" (*Popular Astronomy*, 1897), and "Scales of Seeing" (*Popular Astronomy*, 1898).

Since it was first put in practice—at Arequipa and Flagstaff—much further knowledge about what makes good or bad seeing has been obtained through the study of the air-currents by Mr. A. E. Douglass, for some years connected with this observatory. To his research we are indebted for the practical results, though not for the original detection of the air-currents which make or mar the seeing, and for the practical results which flow from their observation. In the course of this research it has thus been found, for example, that clear-cutness of the limb is not a sure test in planetary observations. The air-currents may be such as to give a sharp limb and poor detail definition, or a poor limb and good detail, or to show both limb and detail clearly. It seems to be a matter of the size of the waves. An observer, judging of a planet as a whole, might easily suppose he was having seeing good enough to show certain detail if it existed, whereas he was not; and *vice versa* he might distrust realities as illusions.

It seems to be absolutely necessary to refer to the stars as a criterion for the reason that otherwise too much is left to the discrimination of the observer. Reference to the condition of the terminator or to any other special feature is too much a matter of individual skill to be generally advisable. A scale to be universal must be as simple and impersonal in practice as it is correct in principle.

Lowell Observatory, Flagstaff, A.T.:
1903 *March* 9.

Transits observed with the Durham Almucantar between 1901 *November* 23 *and* 1902 *December* 15.

By Prof. R. A. Sampson.

The Durham Almucantar has now been in use upon a settled plan for a sufficiently long time to show the quality of the work it can do. It seems of interest to publish the results without delay, although I do not doubt that a few years more of observation will improve them materially. I have therefore collected the observations made between 1901 November 23 and 1902 December 15, which have been taken and reduced upon a uniform plan, that may be looked upon as a final and approved one except in small points of detail.

The question which I proposed to solve with the almucantar was its title to compete with the finest transit circles in the fundamental work of finding star places, and in the course of this study to determine how to use it to the best advantage, and what were its weak and strong points. In fact, I proposed a thorough and extended revision and continuation of Mr. S. C. Chandler's original investigation, published in vol. xvii. of the *Harvard Annals*.

Striking as Mr. Chandler's work is, it is usually found that an inventor's methods are liable to improvement, and some of the modifications I have introduced are not immaterial.

Almost all the observations recorded below were taken by Mr. F. C. H. Carpenter. It was my original intention to share equally with him in the observations, and it is my hope to do so at some future time ; but the earlier experimental work and the various changes made before the observing ran smoothly, with theoretical investigations, revision of reductions, and discussion of results absorbed the time I could spare so completely that I have been obliged for the present to give up the additional heavy tax that observing imposes.

Meanwhile it is perhaps as well to offer a completely homogeneous group by one observer as a specimen of what the instrument will do.

§ 1. *The Durham Almucantar as at present used.*

A general description of the almucantar as set up at Durham was published in *Monthly Notices*, 1900 June (vol. lx. p. 572).

Without repeating these details I may say briefly that it is an instrument for taking transits, with horizontal wires, movable in azimuth, and clamped at the altitude of the pole. Its characteristic feature is that the movable parts are floated on a mercury bath, and it is in the first place assumed that after a disturbance such as arises from setting to a fresh azimuth, the telescope settles down to the same Z.D. as before. Each star

makes a transit east and a transit west of the meridian, cutting the spider lines obliquely at an angle equal to its own hour-angle ; the azimuth at which any star transits is roughly computed for the purposes of setting ; the hour-angle is rigorously computed from assumed data for the purpose of comparing these with the result of observation. The observations are exclusively time observations, and are taken with Professor Hough's printing chronograph described below. The theory of the instrument and the method of reducing and combining the observations are also given in full in subsequent sections. I will add only a description of some changes and additions made to the instrument since the description was published.

The original plate of lines for observing consisted of lines ruled upon a plate of glass : this was discarded after trial, and a plate carrying spider lines replaced it. There is one vertical line and twenty-seven horizontal ones. Twenty-five of these in five tallies of five lines each are designed for chronograph observations ; the other two come in if there is occasion to observe with eye and ear. The chronograph lines are very close together, separated by 0·005 inch in the same tally, and by 0·01 inch between two tallies, which is about 14″ and 28″ upon the sky. It is desirable to have the lines as close as is found safe and convenient for observing in order to keep within a moderate distance of the centre of the field the transits of stars which cross the lines at a small angle. The wire intervals and their inclination to the horizon are discussed in detail below.

The original eye-piece was inserted in a socket fixed to the telescope tube. It was not possible to slide it, for it is essential that the telescope should not be touched after it has ceased to oscillate. A guard ring carried by an arm independent of the floating parts was provided to rest the eye against in order to prevent accidental disturbance. This was not satisfactory. The outer lines were crossed far from the centre of the field of the fixed eye-piece, and considerable coma was introduced into the images which ruined the observations.

I cleared away the fixed eye-piece and the guard ring, and replaced them by a sliding eye-piece carried by the same arm as formerly carried the guard ring. This eye-piece is therefore independent of the telescope. It worked at once with perfect success. It has adjusting screws to set it in its mean position over the centre of the system of spider lines, and the sliding motion can be made in any direction across the field so as to follow each star at its proper obliquity. After the telescope is set in azimuth, the direction of the slide is set to the proper angle by means of a roughly graduated circle.

When the observations are over, the eye-piece and its slide are withdrawn, and a cap put over the end of the telescope tube to protect the spider lines from injury.

All transits are taken with dark field and bright lines, illuminated by two minute electric lamps.

The telescope as shown in the published photograph is not guarded from wind, and this prevented observation on some nights otherwise fine. In the early months of 1902 an experimental screen was tried with success, and in August the instrument was boxed in almost completely by a screen constructed by Messrs. T. Cooke & Sons. The frame of this screen is of iron and the panels of perforated zinc sheet which allows the free circulation of air, but breaks up the gusts which formerly set the instrument rocking. The framework of this screen is fastened to the trough and to the arm which carries the eye-piece ; all the telescope, from eye end to object-glass, is covered in. The old dew-cap fixed to the O.G. cell is removed, and a hood attached to the screen which covers in this cell and carries a new dew-cap. This screen does its work successfully. Formerly a gust of air, impinging, I suppose, on the float or dew cap or eye-end would set the telescope rocking in Z.D. Now the only effect of a gust I can discover is a very slow motion between the small limits of azimuth allowed for clearance, and this probably has no sensible effect whatever in Z.D.

The screen is otherwise convenient, for there is plenty of space to spare within it, and it has been provided with a shelf on which is put a small accumulator for illuminating the wires.

No gas or oil lamp is used in the telescope room. The azimuth circle is read by small electric lamps from this accumulator, which also lights up a sidereal watch which hangs upon the frame of the wind screen.

The movable dome consists of almost the whole roof of the telescope room, which is run aside over the roof of a neighbouring room. When open the observing room consists of nothing more than four walls. Judging from the steady definition we get, I should say the circumstances are favourable for good observing.

§ 2. *Theory of the Individual Observation.*

An observation with the almucantar, as with most other instruments, yields an equation defining corrections to assumed data. Such an equation was given by Mr. Chandler, and the following treatment is not fundamentally different from his ; but I believe it will be found more straightforward, as it develops the theory of all the corrections from a single original equation ; it is also in some minute respects more exact.

Defining the colatitude circle as the horizontal small circle or almucantar which passes through the pole, call

ζ the true elevation of an object above the colatitude circle ;

δ its true declination ;

t its hour-angle, + West, − East ;

ϕ the true latitude ;

then we have the equation

$$\sin(\phi+\zeta)=\sin\phi\sin\delta+\cos\phi\cos\delta\cos t \quad \ldots \quad (1)$$

Further, let ϕ_o be the adopted latitude of the observatory, and let a table be computed giving t_o for every value of the argument δ_o from the equation

$$\sin\phi_o=\sin\phi_o\sin\delta_o+\cos\phi_o\cos\delta_o\cos t_o \quad \ldots \quad (2)$$

Then if δ_o be the adopted declination of the object, we write

$$\phi=\phi_o+\Delta\phi \qquad \delta=\delta_o+\Delta\delta$$

and $\Delta\phi$, $\Delta\delta$ will be so small that their squares may in all cases be neglected ; then equation (1) may be written

$$\sin\phi_o+\cos\phi_o\sin(\zeta+\Delta\phi)-\sin\phi_o\,.\,2\sin^2\frac{\zeta+\Delta\phi}{2}$$
$$=\sin\phi_o\sin\delta_o+\Delta\phi\cos\phi_o\sin\delta_o+\Delta\delta\sin\phi_o\cos\delta_o$$
$$+(\cos\phi_o\cos\delta_o-\Delta\phi\sin\phi_o\cos\delta_o-\Delta\delta\cos\phi_o\sin\delta_o)\times$$
$$\left(\cos t_o-\sin t_o\sin(t-t_o)-\cos t_o\,.\,2\sin^2\frac{t-t_o}{2}\right)$$

where $\Delta\phi$, $\Delta\delta$ are supposed expressed in circular measure. In this it is plain that we may drop the terms $[\zeta, \sin(t-t_o)]\times[\Delta\phi, \Delta\delta]$, since their retention is equivalent to increasing by insensible amounts the coefficient of $\sin(t-t_o)$ or of ζ ; further

coeff. of $\Delta\phi=\cos\phi_o\sin\delta_o-\sin\phi_o\cos\delta_o\cos t_o$
$=(\sin\delta_o-\sin^2\phi_o)\sec\phi_o$.

,, ,, $\Delta\delta=\sin\phi_o\cos\delta_o-\cos\phi_o\sin\delta_o\cos t_o=\cos\phi_o\cos t_o$

Hence the equation reads

$$\sin\zeta-\tan\phi_o\,.\,2\sin^2\frac{\zeta}{2}+(1-\sin\delta_o)\sec^2\phi_o\Delta\phi=\cos t_o\Delta\delta$$
$$-\cos\delta_o\sin t_o\sin(t-t_o)-\cos\delta_o\cos t_o\,.\,2\sin^2\frac{t-t_o}{2} \quad \ldots \quad (3)$$

Now if α_o=assumed R.A. of object ;
$\alpha=\alpha_o+\Delta\alpha$, the true R.A. ;
θ =clock time of observation ;
$\theta+\Delta\theta$=true time ,, ,,

then we have

$$t=\theta+\Delta\theta-(\alpha_o+\Delta\alpha)$$

and the assumed sidereal time is

$$\theta_o = a_o + t_o$$

so that if O − C stands for *Observed Time minus Computed Time*

$$O - C = \theta - \theta_o$$

and
$$t - t_o = O - C + \Delta\theta - \Delta\alpha \quad \ldots \quad \ldots \quad (4)$$

Equations (3) and (4) are fundamental equations of the almucantar.

Now consider the equation

$$\zeta + (1 - \sin\delta_o)\sec^2\varphi_o \Delta\phi = \cos t_o \Delta\delta - \cos\delta_o \sin t_o (O - C + \Delta\theta - \Delta\alpha) + R \quad \ldots \quad (5)$$

This is identical with (3) (4) provided

$$R = \zeta - \sin\zeta + \tan\varphi_o \, 2\sin^2\frac{\zeta}{2} + (t - t_o - \sin(t - t_o))\cos\delta_o \sin t_o - \cos\delta_o \cos t_o \, . \, 2\sin^2\frac{t - t_o}{2} \quad \ldots \quad (6)$$

It is now necessary to define ζ with reference to the tallies of spider lines.

Let the true Z.D. of an object at its transit across the rth spider line, where this spider line meets the cross line perpendicular to it, be $\frac{\pi}{2} - (\phi + \zeta_r)$, and let γ_r be the inclination of this line to a true horizontal direction, reckoned positive when the west end is lowest, and b_r the distance from the intersection at which the transit takes place ; then

$$\sin(\phi + \zeta) = \sin(\phi + \zeta_r)\cos b_r - \cos(\phi + \zeta_r)\sin b_r \sin\gamma_r$$

or with sufficient accuracy for all purposes

$$\sin\zeta - \tan\phi_o \, 2\sin^2\frac{\zeta}{2} = \sin\zeta_r - \tan\varphi_o \, . \, 2\sin^2\frac{\zeta_r}{2} - \tfrac{1}{2} b_r^2 \tan\phi_o - b_r\gamma_r$$

Moreover, if T be the hour-angle of transit across the central cross line

$$b_r = (t_r - T)\cos t_o \cos\delta_o ;$$

hence the general equation for the rth wire is

$$\zeta_r + (1 - \sin\delta_o)\sec^2\phi_o \Delta\phi = \cos t_o \Delta\delta - \cos\delta_o \sin t_o (O_r - C + \Delta\theta - \Delta\alpha) + R_r \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

where

$$R_r=\zeta_r-\sin\zeta_r+\tan\phi_0\,.\,2\sin^2\frac{\zeta_r}{2}-\tfrac{1}{2}(t_r-T)^2\cos^2 t_0\cos^2\delta_0\tan\phi_0$$
$$-\gamma_r(t_r-T)\cos\delta_0\cos t_0$$
$$+(t_r-t_0-\sin(t_r-t_0))\cos\delta_0\sin t_0-\cos\delta_0\cos t_0\,.\,2\sin^2\frac{t_r-t_0}{2}\ldots\quad(8)$$

Lastly, ζ_r determines the true Z.D. of the object at the time of observation, and for a fixed spider line ζ_r varies with the state of the atmosphere. We have the equation

$$\zeta_r+r=z_r$$

where r is the refraction, and $90^\circ-\phi-z_r$ the actual Z.D. of the rth spider line at its intersection with the cross line. Further neglecting differential refraction among the spider lines we may put

$$\zeta_r=z_r-r_r-\Delta r$$

where

r_r is the refraction for the mean state of atmosphere and the apparent Z.D. $90^\circ-\phi-z_r$;

$r_r+\Delta r$ is the same for the true state of atmosphere;

so that Δr is taken the same for all the lines, and r_r independent of the state of the atmosphere.

Then in equation (7) we must write z_r-r_r for ζ_r, and replace R_r by $S_r=R_r+\Delta r$. If, then, we tabulate S_r, and apply it as a correction, we shall have a correct linear equation between z_r-r_r, $\Delta\phi$, $\Delta\delta$, and $O_r-C+\Delta\theta-\Delta\alpha$. It is then required to reduce S_r to its simplest form.

Now it will suffice if S_r be correct to $0''\cdot01$, or in circular measure to 5×10^{-8}. Consider its members in turn, and in doing so it will be unnecessary to distinguish between ζ_r and the wire interval from the mean line.

(i) $\zeta_r-\sin\zeta_r$: if the breadth of the field is as much as $7'$, and the centre line is only a few seconds from the colatitude circle, ζ_r does not exceed $210''$, or, say, $\sin\zeta_r=0\cdot001$, which makes $\zeta_r-\sin\zeta_r=2\times10^{-10}$, which is negligible.

(ii) $+\tan\phi_0\,.\,2\sin^2\frac{\zeta_r}{2}$: or $\tan\phi_0\,.\,\frac{1}{2}\zeta_r^2$, which for lat. $54^\circ\,46'$ is $1\cdot4\times5\times10^{-7}$; hence it must be retained. If the complete tally of spider lines is observed it will yield a mere constant, which may be supposed united with z_r-r_r; but if the outer members of the tally are missed it may yield a sensible correction.

(iii) $-\frac{1}{2}(t_r-T)^2\cos^2 t_0\cos^2\delta_0\tan\phi_0$: if the telescope is carefully set in azimuth, the transit across the central cross line of the field may be taken as the same as the transit across the mean horizontal line of the tally, or $T=t_0$, and further we may take

$$t_r-t_0=+\zeta_r\sec\delta_0\operatorname{cosec}t_0$$

hence this correction may be written

$$-\tfrac{1}{2}\,\zeta_r^2 \cot^2 t_o \tan \phi_o$$

(iv) $-\gamma_r\,(t_r - \mathrm{T})\cos\delta_o \cos t_o$: this becomes $-\gamma_r\,\zeta_r \cot t_o$.

(v) $\{t_r - t_o - \sin(t_r - t_o)\}\cos\delta_o \sin t_o$: this becomes $+\tfrac{1}{6}\zeta_r^3 \sec^2\delta_o$ $\mathrm{cosec}^2\, t_o$, and this is negligible provided sec δ_o cosec t_o does not exceed 16, that is, in lat. 54° 46′ for any star whose declination does not exceed 86°, or taking those near the limit of southern observation whose hour-angle does not fall below $0^h\ 15^m$.

(vi) $-\cos\delta_o \cos t_o \;.\; 2\sin^2 \dfrac{t_r - t_o}{2}$: we may write for this

$$-\tfrac{1}{2}\,\zeta_r^2 \sec\delta_o \cos t_o \,\mathrm{cosec}^2\, t_o$$

The second, third, and last of these terms may be collected into the form

$$+\tfrac{1}{2}\,\zeta_r^2\left[+\tan\phi_o - \cot^2 t_o \tan\phi_o - \sec\delta_o \cos t_o \,\mathrm{cosec}^2\, t_o\right]$$
$$= -\tfrac{1}{2}\,\zeta_r^2 \frac{\tan\phi_o}{\sin^2 t_o}\left[\cos 2t_o + \frac{1}{1+\sin\delta_o}\right]$$

Hence we have the equation

$$z_r - r_r + (1-\sin\delta_o)\sec^2\phi\Delta\phi$$
$$= \cos t_o \Delta\delta - \cos\delta_o \sin t_o\,(\mathrm{O}_r - \mathrm{C} + \Delta\theta - \Delta\alpha) + \mathrm{S}_r$$

where

$$\mathrm{S}_r = -\tfrac{1}{2}\zeta_r^2 \frac{\tan\phi_o}{\sin^2 t_o}\left[\cos 2t_o + \frac{1}{1+\sin\delta_o}\right]$$
$$-\gamma_r\,\zeta_r \cot t_o + \tfrac{1}{6}\zeta_r^3 \sin^2\delta_o \,\mathrm{cosec}^2\, t_o + \Delta r \qquad \ldots\ (9)$$

where in S_r, ζ_r may be treated as the wire interval from the mean wire.

Now suppose that there are twenty-five wires, as in the Durham instrument, and that all of these are observed ; define

$$\bar{z} = \tfrac{1}{25}\Sigma\,(z_r - r_r)$$
$$\mathrm{O} = \tfrac{1}{25}\Sigma\mathrm{O}_r$$

the equation becomes

$$\bar{z} + (1-\sin\delta_o)\sec^2\phi_o\,\Delta\phi$$
$$= \cos t_o\,\Delta\delta - \cos\delta_o \sin t_o\,(\mathrm{O} - \mathrm{C} + \Delta\theta - \Delta\alpha) + \mathrm{S}$$

where

$$\mathrm{S} = -\tfrac{1}{50}\Sigma\zeta^2 \frac{\tan\phi_o}{\sin^2 t_o}\left[\cos 2t_o + \frac{1}{1+\sin\delta_o}\right]$$
$$-\tfrac{1}{25}\Sigma\zeta_r\gamma_r \cot t_o + \tfrac{1}{150}\Sigma\zeta_r^3 \sec^2\delta_o \,\mathrm{cosec}^2\, t_o + \Delta r \ \ldots\ (10)$$

Next suppose that p wires only were observed.

Take $O = \frac{1}{p}\Sigma_p O_r$, where Σ_p covers the actual observations; then

$$\frac{1}{p}\Sigma_p (z_r - r_r) = \frac{1}{p}\{25\bar{z} - \Sigma_{25-p}(z_s - r_s)\}$$

where $_s$ refers to one of the dropped wires

$$= \bar{z} + \frac{1}{p}\{(25-p)\bar{z} - \Sigma_{25-p}(z_s - r)\}$$

$$= \bar{z} - \frac{1}{p} \times \{\text{sum of wire intervals for dropped wires}\}$$

Similarly $$\frac{1}{p}\Sigma_p \zeta_r^2 = \tfrac{1}{25}\Sigma_{25}\zeta_r^2 + \frac{25-p}{p}\cdot\tfrac{1}{25}\Sigma\zeta_r^2 - \frac{1}{p}\Sigma_{25-p}\zeta_s^2$$

or if $$\zeta_s^2 = k_s \times \tfrac{1}{25}\Sigma_{25}\zeta_r^2$$

$$\frac{1}{p}\Sigma_p\zeta_r^2 = \{1 + \frac{1}{p}[(25-p) - \Sigma_{25-p}k_s]\}\cdot\tfrac{1}{25}\Sigma_{25}\zeta_s^2.$$

Again, let $$\gamma_s\zeta_s = l_s \times \tfrac{1}{25}\Sigma_{25}\gamma_r\zeta_r$$

and $$\zeta_s^3 = m_s \times \tfrac{1}{25}\Sigma_{25}\zeta_r^3$$

and we have similar formulæ for the other two corrections.

The equation (10) will now be improved if we unite with $\bar{z}$ the mean part of the term $(1-\sin\bar{\delta_o})\sec^2\phi_o\Delta\phi$ which diminishes to zero as δ_o increases up to $\frac{\pi}{2}$ but does not change sign. If we take an arbitrary fixed angle $\bar{\delta}$, and make the first term $\bar{z} + \{1-\sin\bar{\delta}\}\sec^2\phi_o\Delta\phi$ the second term becomes $(\sin\delta - \sin\bar{\delta_o})\sec^2\phi_o\Delta\phi$, which changes sign at $\delta_o = \bar{\delta}$, and is therefore more readily separated from the first term in solving a group of equations.

Finally turn from circular measure to the measures proper to the different quantities, namely, seconds of time for O, C, $\Delta\theta$, $\Delta\alpha$, and seconds of arc for $\bar{z}$, $\Delta\phi$, $\Delta\delta$; also write

$$z = \tfrac{1}{10}'(\bar{z}'' + \{1-\sin\delta\}\sec^2\phi_o\Delta\phi)$$

$$\Delta\theta^s = \Delta_o\theta^s + y$$

where $\Delta_o\theta$ is a round number adopted in advance of the dis-

cussion of the equation in order to clear out large quantities from O—C;

$$x = \tfrac{1}{10}\Delta\phi''$$

and

$$a = 1{\cdot}5 \cos \delta_0 \sin t_0, \text{ taken always positive}$$
$$b = (\sin \bar{\delta} - \sin \delta_0) \sec^2 \phi_0$$

then the standard equation for a single observation reads, the upper signs referring to a transit east, and lower to a transit west

$$\mp z + ay \mp bx + n = v \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

where $n = a(O' - C' + \Delta_0\theta') + S$

$v = a\Delta\alpha' \mp \tfrac{1}{10} \cos t_0 \Delta\delta''$

and

$$S = \pm\frac{1}{10p}\Sigma\{(25-p)\bar{z}'' - \Sigma_{25-p}(z_s'' - r_s'')\}$$
$$\mp\frac{\sin 1''}{500}\frac{\tan \phi_0}{\sin^2 t_0}\left(\cos 2t_0 + \frac{1}{1+\sin \bar{\delta}_0}\right) \times$$
$$\left[1 + \frac{1}{p}\{(25-p) - \Sigma k_s\}\right] \Sigma_{25}\zeta_r''^2$$
$$-\frac{\sin 1''}{250} \cot t_0 \left[1 + \frac{1}{p}\{(25-p) - \Sigma l_s\}\right]\Sigma_{25}\gamma_r''\zeta_r''$$
$$+\frac{(\sin 1'')^2}{1500} \sec^2 \delta_0 \operatorname{cosec}^2 t_0 \left[1 + \frac{1}{p}\{(25-p) - \Sigma m_s\}\right] \Sigma\zeta_r''^3$$
$$\pm\tfrac{1}{10}\Delta r'' \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

It is necessary to tabulate in the book which gives t_0 with argument δ_0 the quantities a, b, and the different parts of S (excepting $\frac{1}{10}\Delta r$). The first part of S is the correction for dropped wires; the second is for the curvature of the wires, that is, their departure from small circles of constant Z.D.; the third is for the inclination of the wires; the fourth for the curvature of the path of the star.

The angle $\bar{\delta}$ is arbitrary. It would be best to take it so as to divide into two portions of equal area the whole of the sky which comes into view or

$$\sin \bar{\delta} = \sin^2 \phi_0$$

for $\phi_0 = 54° 46'$, this gives $\bar{\delta} = 41° 52'$. In my actual work the angle used has been $\bar{\delta} = 52° 2'$, which is not so good; but I have not judged that the difference was great enough to call for the recalculation of the quantities b and all that depend on them.

§ 3. *Theory of the Combination of Observations.*

The foregoing equation differs slightly in the values of the small corrections and substantially in form from that adopted by Mr. Chandler (*Harvard Annals*, xvii., ch. ii., equation (7)). The choice of form has been determined by two considerations, these being, first, economy of labour in applying the corrections; and, second, the form which expresses correctly the relative weights in determining the different constants of observations taken at different declinations. In the transit circle it is usual to treat observations of equal weight in determining clock correction up to a chosen declination, beyond which they are not used for this purpose at all, and Mr. Chandler followed a similar plan for the almucantar. But it is clear that for the almucantar it would be far nearer the truth to treat all observations wherever taken as of equal weight in determining the constant z the slow motion of the stars of higher declination being compensated by the obliquity of the transits of the lower ones; and that such a treatment is not only plausible but very near the truth is shown by Mr. Chandler's investigation of the errors in Z.D., as determined by groups of stars of different declinations He gives the following table derived from his own results (p. 81) :—

Probable Accidental Error of a Single Observation in Zenith Distance.

Mean δ.	Range in δ.	Prob. Error.	Mean δ.	Range in δ.	Prob. Error.
° 85	° 89–81	″ ±0·35	° 62	° 62–60	″ ±0·43
78	80–77	0·32	55	59–46	0·35
75	76–74	0 47	38	43–33	0·43
72	74–71	0·36	23	27–20	0·44
70	70–67	0·35	15	19–11	0·47
66	67–63	0·36	0	7––5	0·46

And with this table he gives reasons to believe that the increase of probable error at mean declination 75° and below 38° is due to causes which for my purpose are irrelevant. Relying upon these results, I have thrown the fundamental equation into a form which gives to z the same coefficient for all declinations.

To obtain information about an individual star from the fundamental equation (11) it is first necessary to know the instrumental constants z, y, x by means of a combination of all the observations. The best way to do this is to take well-determined stars, assume v to be zero, and combine the resulting

equations by Least Squares. For the almucantar this can be done with very little labour, and here the full advantage is realised of deriving all the unknowns from a single type of equation in place of the many different kinds of observation upon which the transit circle depends. It is only necessary to tabulate with argument δ_o in the book already used for finding t_o, a, b, the values of a^2, ab, b^2, s, as, bs, where $s=-1+a-b$ for transits east, and $+1+a+b$ for transits west. Then when n is determined we have only to form na, nb, ns by the help of Crelle's Tables. If this is the first time the powerful rules of Least Squares have been employed in transit work, I think it may claim to be a material advance, and, besides being theoretically the best, the method has been found a thoroughly practical one in use. The freedom from hesitation as to which observations to use for this or that constant, and how to combine them and the automatic checks upon accuracy which the method supplies, more than make up for the labour it involves.

When x, y, z have been determined and substituted in the equation of condition (11), the residual v is offered as a correction to the star's assumed place, viz. $v=a\Delta\alpha^s\mp\frac{1}{10}\cos t_o\Delta\delta$. The value of v, together with the constant $a=1{\cdot}5\cos\delta_o\sin t_o$, and $\frac{1}{10}\cos t_o$, must be posted to the proper place in the star ledger. But before doing this I have latterly made another step to see whether there is any indication of a progressive change in the value of z in the course of the night. Adopting the values of x, y given by the solution of the normal equations, I have substituted these in the equations of condition, supposing $v=0$, and have ascertained what value of z is required to satisfy the equation of condition. These values of z I have sometimes charted, and from their lie upon the chart have estimated what change has taken place in z, proportionately with the time, or, better, taking the value given by solution of the normal equations as that which corresponds to the mean of the times of observation, I have taken also the mean of the z's preceding this time and also of those following it, and from these have derived the rate of change. Sometimes there is a well-marked indication of change and sometimes there is none. Where any change has been recognised, I compute the corresponding value of z for each observation, and finally adopt v from the equation

$$v=\mp(z_a-z_i)$$

where

$$z_a=z+(t-t_o)\Delta z$$

being the adopted value of z, allowing for the change Δz, and

$$\mp z_i+ay\mp bx+n=0$$

or z_i is the value of z indicated by the individual equation treated as correct.

It will be seen that my method determines the latitude correction $\Delta\phi'' = 10x$ from each night's observations. The solution would be simplified and abridged materially if $\Delta\phi$ were treated as known, as Mr. Chandler has done ; but there are several reasons that determined me to retain $\Delta\phi$ as an unknown in every set of observations from which it could reasonably be derived ; first $\Delta\phi$ is variable, and if it is not treated as an unknown its variations will vitiate v systematically ; again, to compare the values of $\Delta\phi$ obtained night by night will give a better immediate test than any other of how near the truth the solution lies. The observations recorded below were not specially directed towards finding $\Delta\phi$; had that been so, as great a range as possible in declination would have been observed, so as to make Σb^2 large while Σb, Σab were small ; but there are special difficulties in connection with working with the limiting declinations that determined me to postpone any such investigation till I was satisfied with the work of the instrument at declinations not complicated by these difficulties. Hence the individual determinations of $\Delta\phi$ are of no great weight, and possess peculiarities to which I shall draw attention in the proper place.

Observations of the same star must be made both east and west before we can determine the corrections of its coordinates. These observations may be separated by a considerable interval, for it is not practicable to get observations of many stars east and west on the same night. As a rule, if the observing is done at the same time of day, say from 9 P.M. to midnight, in this time a given star will transit as an east star for a space of forty-five days, and afterwards, at an interval which increases with the declination from zero to half the year, as a west star for forty-five days. In these periods a number of east observations and a number of west observations must be secured if any corrections to catalogue places are to be derived.

It is of the essence of the foregoing method of solution that the residuals for all stars, whether their declinations are high or low, are presumably of equal magnitude. There is no more reason to expect a large residual from *Polaris* than from *Pollux*. Hence the measures of the error in the two coordinates are given by the reciprocals of the two coefficients in the equation

$$v = 1{\cdot}5 \cos\delta_0 \sin t_0 \Delta a^s \mp \tfrac{1}{10} \cos t_0 \Delta\delta''$$

Thus in low declination the almucantar determines declination better than R.A., and in high declinations reverses this, and the question of the almucantar *versus* the transit circle may be put briefly : How small can the probable error of v be made, and what range of declination can we establish over which a certain error in v will not be outweighed by the factors $1{\cdot}5 \sin t_0$, $\frac{1}{10}\cos t_0$, which do not figure in the theory of coordinates found by the transit circle ?

§ 4. *Reductions and other Calculations for the Almucantar as used at Durham.*

In judging the convenience of a method designed for permanent use no great account need be taken, as a rule, of labour spent on calculations which can be done once for all and fixed in the form of an auxiliary table. For the almucantar such an auxiliary table must give with argument δ_o the quantities t_o, a, b, &c. in the form most convenient for use. Assuming the adopted latitude ϕ_o is correct within a second, or even within several seconds, this will never need to be remade, and hence trouble will be well spent that makes it more convenient. The following is a specimen of the table I use: From $\delta_o = 25°$ to $\delta_o = 90°$ the left-hand page shows the value of t_o for every minute of arc, with D, which is the change in t_o for a single second, computed for latitude $\phi_o = 54° 46' 6''{\cdot}2$; thus:

No. 1. *Hour Angle and Constants Book.*

$\delta_o = 38°$ $\quad$ $t_o = 3^h\ 5^m \ldots 3^h\ 10^m$

′	t_o m s	D	′	t_o m s	D	′	t_o m s	D
0	5 17·449	0807	20	6 53·930	0801	40	8 29·507	0793
1	22·297	0808	21	58·730	0800	41	34·263	0792
2	27·138	0807	22	7 3·527	0800	42	39·015	0792
3	31·979	0807	23	8·322	0799	43	43·765	0792
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Thus, if, for example, the apparent declination of a star at date as derived from the catalogue be 38° 41′ 39″·4, using Crelle's Tables we apply $39''{\cdot}4 \times {\cdot}0792$ to $3^h\ 8^m\ 34^s{\cdot}263$, giving $t_o = 3^h\ 8^m\ 37^s{\cdot}383$ as the computed hour-angle of its transit.

Between $\delta_o = 25°$ and $\delta_o = 21°$ it is necessary to take account of second differences and of third differences between $\delta_o = 21°$ and $\delta_o = 19°\ 32'$, which is the limit for latitude 54° 46′, and the table is arranged accordingly.

On the right-hand page of the same opening stand all the subsidiary quantities that will be wanted at any stage of the work, namely A, the azimuth setting required to find the star, a, b, the coefficients defined in § 2, viz. $a = 1{\cdot}5 \cos \delta_o \sin t_o$, $b = (\sin \delta - \sin \delta_o) \sec^2 \phi_o$, in which δ has been taken at 52° 2′, a^2, ab, b^2, s, as, bs, both east and west, for forming normal equations, $\cos t_o$ which is required in the star ledger as the coefficient of $\frac{1}{10}\Delta\delta''$, and the correction for the curvature of the wires, being the second member of the correction S of § 2,

excepting the factor referring to dropped wires, which depends upon the determination of wire intervals given later. The third member of S, being the correction for inclination of the wires, should also be added ; but till now I have not made the observations or discussions necessary for finding it, and have treated it as zero. The fourth member I have also neglected, since, excepting for the original determination of wire intervals which were reduced by Mr. Chandler's method, I have taken no transits in which it would be sensible.

The upper sign refers to the transit east and the lower sign to transit west ; the small numbers are differences for 10′.

No. 1. *Hour Angle and Constants Book.*

$\delta_0 = 38°$.

	0′		10′		20′		30′		40′		50′		60′
A	8° 1′ 15	24	8° 1′ 29	24	8° 1′ 53	24	8° 2′ 17	24	8° 2′ 41	23	8° 3′ 4	24	8° 3′ 28
a	·855	1	·856	1	·857	1	·858	0	·858	1	·859	1	·860
b ∓	·519	7	·512	7	·505	6	·499	7	·492	7	·485	7	·478
a^2	·731	2	·733	1	·734	2	·736	0	·736	2	·738	2	·740
$a\,b$ ∓	·444	6	·438	5	·433	5	·428	6	·422	5	·417	6	·411
b^2	·269	7	·262	7	·255	6	·249	7	·242	7	·235	7	·228
E $s-$	·664	8	·656	8	·648	7	·641	7	·634	8	·626	8	·618
$a\,s-$	·568	7	·561	5	·556	6	·550	6	·544	6	·538	7	·531
$b\,s+$	·344	8	·336	9	·327	7	·320	8	·312	9	·303	8	·295
W $s+$	2·374	6	2·368	6	2·362	5	2·357	7	2·350	6	2·344	6	2·338
$a\,s+$	2·030	3	2·027	3	2·024	2	2·022	6	2·016	2	2·014	3	2·011
$b\,s$	1·232	20	1·212	19	1·193	17	1·176	20	1·156	19	1·137	20	1·117
Cos t_0	·691	3	·688	2	·686	3	·683	2	·681	3	·678	3	·675
Curvature ∓	·007		·007		·007		·007		·007		·007		·006

All the interpolations can be done at sight from this table with the greatest ease ; the differences never became large excepting for A, which requires more detailed tabulation below $\delta_0 = 23°$.

We must next make a setting book, showing the azimuth and the sidereal time at which each star in the observing list makes its transit. My observing list consists at present of all stars in the *Nautical Almanac* and Berlin *Astronomisches Jahrbuch*, with declinations exceeding $+19° 35′$. The hour of its transit is $\alpha - t_0$ east, and $\alpha_0 + t_0$ west, where α_0 is its R.A. taken from the catalogue. This is entered to the nearest minute of time. Along with it is entered the azimuth, to which the telescope must be

set (A). The column B gives the reading on a second vernier 90° from A, which it is more convenient to read in some positions of the instrument. To avoid errors of setting, transits west are entered in this book in red ink (below with an asterisk) ; the whole is arranged in a table in order of time. Thus, for example, at sidereal time 19^h, we have the following :—

No. 2. Setting Book, 1902.

19^h.

Name.	Mag.	R.A.	θ.	A.	B.
		h m	h m	° ′	
43 Cephei ...	4·3	0 55	19 8	172 37	
*ζ Herc.	3·1	16 38	19 9	65 1	24 59
* Groomb. 2164 B.J.	5·8	14 49	19 19	126 6	36 6
*110 Herc. B.J.	4·0	18 41	19 24	17 17	
21 Cass. B.J.	6·0	0 39	19 24	152 54	
*ε Herc.	4·0	16 57	19 24	62 59	27 1
⋮	⋮	⋮	⋮	⋮	⋮

After a few years' use this book will require revision, since the tabulated azimuths will be a little out of truth owing to precessional changes in declination.

It is inadvisable to observe at less intervals than about $2\frac{1}{2}$ clear minutes. Hence we must choose between 43 *Cephei* and ζ *Herculis*, for example. I have aimed at getting a considerable number of observations of each star, and in place of observing these two stars on alternate nights I have for the present observed the latter exclusively. But since it is necessary to get transits east and west in order to derive corrections to the two coordinates, it is occasionally advisable to observe stars on alternate nights which come at nearly the same time, as 21 *Cassiopeiæ* and ε *Herculis* in the above list, in order not to sacrifice the observations made in the contrary phase. These disabilities, as far as they can be so called, are not peculiar to the almucantar, but present themselves also in the transit circle.

All the observer enters in his note book is the name of the star, its R.A., and the catalogue (*N.A.* or *B.J.*) from which it is derived.

The stars transit obliquely, each cutting the wires at an angle equal to its own hour-angle, and it is necessary after the telescope is set in azimuth to set the slide of the eye-piece so as to cross the wires at the same angle. This is done by help of a small table or chart hanging in the observing room, showing the hour-angle for any azimuth.

The third book required is the reduction book, in which the quantities n of equation (11), § 2 are derived from the observations. Below is a specimen of this book.

No. 3. *Reduction Book.*

Observer : C. *Date :* 1902 *Nov.* 17.

	No. of Star.	1	2	3
	Name	η Pegasi W.	ξ Persei E., B.J.	β Pegasi W., B.J.
	Notes	2	2	2
	α_o	$22^h\ 38^m$	$3^h\ 53^m$	$22^h\ 59^m$
	δ_o	$29°\ 43'\ 6''{\cdot}0$	$35°\ 30'\ 40''{\cdot}3$	$27°\ 33'\ 38''{\cdot}1$
		h m s	h m s	h m s
1	Obsd. Mean ...	0 57 25·536	1 0 0·607	1 2 44·621
2	Corrn. Chron. ...	−·042	−·052	−·043
3	Corrn. 0^h S.T. ...	−·004	−·004	−·004
4	Compt. α ...	1 21 32·130	20 7 18·090	1 0 55·065
5	E t_o ...	2 18 47·543	2 52 42·293	2 3 28·010
6	E $+D\Delta\delta$ ...	+·665	+3·518	+4·789
7	W. Compt. Do....	21 44 11·792		21 56 27·201
8	Personality ...			
11	Sum = O−C ...	+9·412	+4·452	+6·840
12	$\Delta_o\theta$	−5·750	−5·750	−5·750
13	(11)+(12) ...	+3·662	−1·298	+1·090
14	(13)×α ...	+2·714	−1·085	+·744
15	Curv. and Incl....	+·021	−·010	+·030
16	Refraction ...	−·112	+·112	−·112
17	Dropped Wires	(24, 25) −1·881		
20	Sum = n ...	+0·742	−0·983	+0·662
21	v	+·09	+·01	−·02

In this form, the space *Notes* refers to the seeing 1 to 5, 1 being perfect. α_o is a rough value, δ_o is the exact apparent declination at date as given by interpolation from the catalogue.

1 and 2. *Obs. Mean* and *Corr. Chron.* are sufficiently explained below in describing the chronograph.

3. *Corr.* 0^h S.T. is the allowance for clock rate, entered after a rough examination has shown what is the approximate clock error.

4. This is the complement of the apparent R.A. at date derived from the catalogue.

5 and 6. These together give the hour-angle corresponding

to the value of δ_o above derived from the book No. 1, where it is computed.

7. For a star transiting west, after writing down 5 and 6, we strike them through and write instead the complement of their sum.

8. Personality. No allowance has been made so far under this head.

The sum of the quantities 1, 2, 3, 4, with 5, 6, or with 7, gives O—C ; the greater part of this is usually clock error ; in the present case the clock correction is estimated at sight to be $-5^{s}\cdot750$, and this quantity ($\Delta_o\theta$) applied to each sum. The sum $O-C+\Delta_o\theta$ is now multiplied by a, taken from the book No. 1, and the different terms of S are applied to it.

Barometer and thermometer for refraction are taken at the beginning and end of the series of observations, and Δr, the correction to be applied to the mean refraction, is computed from the table given with the Greenwich observations for 1898 : this is done in a moment, as the zenith distance is always the same. From this the hourly rate of change of refraction is calculated : it is assumed to be uniform, and indeed it appears to vary very little from night to night, coming out repeatedly at about $+0''\cdot1$ per hour. In accordance with the formula for S § 2, (12), refraction is applied with its natural sign east, and reversed sign west.

17. The correction for dropped wires is taken without multiplication by any factor from the table of wire intervals.

20. The sum 14, 15, 16, 17 is the quantity n, the absolute term of the equation of condition, and is carried to the book No. 4, where these equations are solved. The residual after their solution, v, is carried back and entered in (21) as well as in the star ledger.

In the next book, No. 4, the equations derived from the observations are collected in the following form. The numbers inclosed in brackets are entered after the solution is made and in the original are written in red.

No. 4. *Solution*

Date : 1902 November 17.

No.	±1.	a.	$\pm b$.	s.	n.	v.	log.
1	+1	+·741	+·880	+2·621	+·742		
	(−·744)	(+·168)	(−·077)			(+·089)	(−8″·33)
2	−1	+·836	−·624	−·788	−·983		
	(+·745)	(+·190)	(+·055)			(+·007)	(−7·38)
3	+1	+·683	+·979	+2·662	+·662		
	(−·746)	(+·155)	(−·086)			(−·015)	(−7·31)
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

In filling up this table a, b, s, aa, ab, bb, as, bs, are read out of the book No. 1 with argument δ_0. n is then carried in from the book No. 3, as we have just seen ; an, bn, sn are formed by help of Crelle's Tables, and the normal equations are then complete when the columns are added, and this is done very rapidly with the Comptometer, especially if positive and negative quantities are separated by setting the former a little to the left and the latter a little to the right in the columns. In taking these sums we must remember to affect a, b with the sign of unity as it stands in the first column, for we are seeking not Σa, but $\Sigma(\pm 1 \times a)$.

On the same page is a ruled form for solving the normal equations ; the solution gave in this case $x = -\cdot 0879$, $y = +\cdot 2266$, $z = -\cdot 7616$, indicating $\Delta\phi = -0''\cdot 879$, the clock correction at 0^h S.T. $= -5^s\cdot 750 + 0^s\cdot 227 = -5^s\cdot 523$, (the quantity $-5^s\cdot 750$ being what was empirically applied in book No. 3 in order to diminish the residuals), and the mean collimation constant $= -7''\cdot 616$.

I now take the constant $-\cdot 0879$ and multiply it by the coefficients b, and similarly $+\cdot 227$ is multiplied by the coefficients a : these give the numbers inclosed in brackets. Then in order that the first equation should be exact, giving zero residual we must have $z = -(\cdot 742 + \cdot 168 - \cdot 077) = -\cdot 833$, so that the first equation alone indicates a collimation constant $-8''\cdot 33$. Similarly the second equation alone indicates $-7''\cdot 38$, and the third $-7''\cdot 31$, and if all the equations are so treated, and we collect the indications of the first half (11 observations) and of the second half (10 observations), we find the means :—at $1^h\ 26^m$, $10z = -7''\cdot 52$; at $2^h\ 41^m$, $10z = -7''\cdot 72$; while the general solution gave at $2^h\ 3^m$, $10z = -7''\cdot 62$; hence the rate of change per hour $10\Delta z = -0''\cdot 16$, and I adopt for this night $10z = -7''\cdot 62 - 0''\cdot 16(\theta - 2^h\ 3^m)$. The values given by this formula are entered in the second column, and the residuals are the differences between the numbers z as standing in the second

Book.

Observer : C.

aa.	$\pm ab$.	*bb.*	*as.*	*bs.*	*an.*	*bn.*	*sn.*
+·549	+·652	+·774	+1·943	+2·305	+·550	+·653	+1·945
+·699	−·522	+·389	−·659	+·490	−·822	+·613	+·775
+·466	+·669	+·959	+1·818	+2·608	+·452	+·648	+1·762
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

and in the eighth columns with the proper sign. Finally the instrumental constants, with a note of the mean residual, are collected at the end of this book, and the residuals are posted to the individual stars in the star ledger.

The star ledger is the last of the books (No. 5). There is little to remark about it ; a single entry will explain it.

38	
α Aurigæ.	
$5^h\ 9^m\ 26^s{\cdot}888$	
$45°\ 53'\ 55''{\cdot}02$	
·855	∓·574
1901	
✱ Dec. 27	−·04
1902	
Oct. 20	−·04
,, 30	·00
Nov. 7	−·02
,, 10	+·02
,, 12	−·08
,, 17	+·01
Dec. 15	(+·05)
1902	
Feb. 28	−·11
✱ March 10	−·05
✱ April 17	−·11

The place of the star is the mean place for the year 1902 taken from the catalogue, in this case the *Nautical Almanac*. The numbers that follow are the coefficients multiplying $\Delta\alpha^s$ and $\frac{1}{10}\Delta\delta''$ in the expression which makes up the residual v, the second member being negative east, positive west. Then follow the separate residuals, the first set representing transits east, the second transits west. The asterisk indicates that I was observing ; the others are Mr. Carpenter's. The bracket round the observations of December 15 indicates that the whole set was condemned, as there was something abnormal in 10z as indicated from the separate observations. Taking the means of what was observed, and omitting December 15, the outcome of these observations is the two equations

$$\cdot 855\ \Delta\alpha^s - \cdot 0574\ \Delta\delta'' = -\cdot 021$$
$$\cdot 855\ \Delta\alpha^s + \cdot 0574\ \Delta\delta'' = -\cdot 090$$

or

$$\Delta\alpha^s = -0^s{\cdot}065 \quad \Delta\delta = -0''{\cdot}60$$

§ 5. *The Printing Chronograph.*

The transits recorded below, excepting those of close circumpolars taken for determining wire intervals, were taken with the printing chronograph designed by Professor G. W. Hough, of Dearborn Observatory. It was made by a Chicago firm, but its success in working is, I believe, entirely due to the pains Professor Hough most kindly took in examining and correcting the essential parts before it was sent to me.

The instrument is the same, except for minor details, as described by Professor Hough in the Annual Report of the Chicago Astronomical Society for 1885 and 1886; but as I believe there is no other example of it outside the United States, and it is not nearly so well known as it should be, I add sufficient description to make the following results intelligible.

There are three wheels revolving side by side, with type cut in relief upon their rims. The first revolves once in an hour, and bears the numbers 0 to 59 upon it for the minutes; the second revolves once a minute and also bears the numbers 0 to 59 for the seconds: these two move forward by steps upon a signal sent each second by the sidereal clock. The third wheel revolves once a second: it is driven by a different train of clockwork; it does not move by steps, but rotates continuously, and can be regulated to run faster or slower. If it is running truly with the sidereal clock the clock signal does not affect its running; if it is running fast it is detained at a certain point of its revolution until the signal comes and lifts an arm which it cannot pass; it is set to run a little fast, so that the signal acts as a slight check upon its going. If then its running should fluctuate and fall slow, the absence of this check acts so as to make it recover; but it must never be allowed to fall seriously slow, or the signal will fail to exercise any true check at all. This wheel has the even numbers 0 to 98 cut upon its rim, so that an odd hundredth of a second is indicated by the neighbouring even ones. Above these wheels an inked ribbon is moved slowly forward, and above this a strip of paper about two inches broad is drawn from a roller as required; above this, again, are three small hammers which, on a signal from the observer, strike the paper against the revolving wheels, and thus print the time of his observation. These hammers, if moved down slowly, stand clear above the type wheels, but they are carried by long arms flexible downwards, so that when suddenly depressed they fly below their equilibrium position and strike the type wheels without stopping them. The paper is moved forward by a third train of clockwork by a contrivance which acts automatically after a signal is sent, or may be actuated independently so as to leave any desired space between successive records.

There is also a key which when held down causes the clock signal to act also as a printing signal, so that for as long as

desired the chronograph will print the times that correspond to successive clock signals, and thus show if it is running fast or slow.

The minute wheel is first set in agreement with the clock, and the second signals set going when the clock and the second wheel are also in agreement. The key, which I call the clock key, viz. that which causes the clock to print when it signals, is then held down for a few seconds, and the record examined. It is satisfactory if it prints, say, $+0^s{\cdot}03$ or thereabouts fast of the clock, assuming the wheel is so set on its axle as to print 0·00 when the check is just not acting. Then going to the telescope the observer holds in his hand a piece leading from the chronograph and bearing three keys. About fifteen seconds before the star begins its transit he holds down for three or four seconds the clock key, and thus gets a record of the rate at which the chronograph is at that instant running ; he then puts down the spacing key, moving the paper forward about an inch, then takes the transits over the twenty-five wires in the usual way with the recording key, puts in another space, holds down the clock key for another three or four seconds, and finally puts in enough space to allow the paper to be afterwards cut in sections and the necessary particulars of each star inserted. It is verified at the beginning and end of the night's observations, and from time to time in the middle, that the chronograph is printing correctly in agreement with the clock, and has not by any accident dropped a second—a thing which can only happen if the clock signal fails to pass.

Then to reduce the observation so made the stars are identified, their names written in, the paper cut in strips one to each star, missing wires marked, and any chance obscurity of printing cleared, and lastly the mean of all the wires observed is carried to the transit book, together with the mean, with sign reversed, of the record given by the clock key. The former corrected by the latter is taken as the time of transit. There is no time spent in deciphering the record as in the common drum chronograph, and there is no necessity to transcribe into the book the details of the transit. The slips containing the transits of each night, together with the checks upon the agreement of clock and chronograph, are fastened in a bundle and kept. The additions, which with twenty-five wires are very heavy, are invariably done with Felt and Tarrant's Comptometer, an invaluable adding arithmometer.

The fluctuations in the running of the chronograph in the course of one night are very small, as may be seen from the amounts allowed in correction of the transits of successive stars ; for example, on 1902 Nov. 7, between $0^h\ 23^m$ and $1^h\ 54^m$ for the fifteen stars observed that night, these amounts were $-0^s{\cdot}038$, $-0^s{\cdot}042$, $-0^s{\cdot}026$, $-0^s{\cdot}036$, $-0^s{\cdot}024$, $-0^s{\cdot}022$, $0^s{\cdot}000$, $-0^s{\cdot}010$, $-0^s{\cdot}006$, $-0^s{\cdot}015$, $-0^s{\cdot}032$, $-0^s{\cdot}028$, $-0^s{\cdot}018$, $-0^s{\cdot}025$, $-0^s{\cdot}005$; on November 10, between $0^h\ 29^m$ and $1^h\ 54^m$, the amounts were $-0^s{\cdot}073$, $-0^s{\cdot}060$, $-0^s{\cdot}044$, $-0^s{\cdot}048$, $-0^s{\cdot}048$,

$-0^s{\cdot}046$, $-0^s{\cdot}044$, $-0^s{\cdot}041$, $-0^s{\cdot}040$, $-0^s{\cdot}020$, $-0^s{\cdot}023$, $-0^s{\cdot}024$, $-0^s{\cdot}042$, $-0^s{\cdot}040$, $-0^s{\cdot}038$; and these are fairly representative of the running. It seems fair to assume that any irregularity in the running as between two stars on the same night, or between the deduced clock corrections on different nights, is absolutely eliminated.

It remains to be examined what is the probable error of printing a correctly sent signal. Professor Hough's manner of testing this was to cause a mean-time clock to send a signal to the recording circuit once a minute ; by this device the printing was tested at every fraction of a second in turn.

Testing my chronograph thus before it was sent from America, Professor Hough found the probable error of a single print was $\pm 0^s{\cdot}013$. I repeated this test when I received the instrument, attaching a roughly made signal apparatus to a clock whose rate was for the time being made approximately mean-time rate. On 1901 October 31 this clock sending signals once a minute lost in 27 minutes $4^s{\cdot}44$ on the sidereal clock, or at the rate of $0^s{\cdot}165$ per minute. Using this rate the difference between the recorded and computed times of the signals were (in the sense Recorded—Computed), $-0^s{\cdot}03$, $+0^s{\cdot}01$, $-0^s{\cdot}02$, $-0^s{\cdot}03$, $0^s{\cdot}00$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}02$, $+0^s{\cdot}03$, $-0^s{\cdot}01$, $+0^s{\cdot}01$, $-0^s{\cdot}01$, $+0^s{\cdot}04$, $-0^s{\cdot}01$, $0^s{\cdot}00$, $+0^s{\cdot}01$, $0^s{\cdot}00$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $+0^s{\cdot}01$, $-0^s{\cdot}02$, $-0^s{\cdot}02$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, $-0^s{\cdot}01$, which gives as the probable error of a single print $\pm 0^s{\cdot}011$. It must be remembered that this error is not due to the chronograph alone ; if e is that of the chronograph and e' that of the signal apparatus, the amount above is equal to $(e^2+e'^2)^{\frac{1}{2}}$, and in this case the signal apparatus was very far from perfect. It is therefore safe to conclude that the probable error proper to the chronograph is barely sensible in amount, and does not reach $\pm 0^s{\cdot}010$.

§ 6. *The Wire Intervals and other Details of the Observations*

The plate at the principal focus of the object-glass carries one vertical and twenty-seven horizontal spider lines ; the horizontal lines I number 0 to 26, starting with that of greatest Z.D., that is, the line which an east star transits first. These lines are grouped in five tallies of five lines each, with two outside lines, 0 and 26 ; the lines 0 and 26 are used only for eye and ear observations (should there be occasion to take such), and the group of wires 0, 1, 7, 13, 19, 25, 26 are approximately equally spaced.

The interval between different tallies is roughly $30''$, or 0·01 inch, and between successive lines of the same tally $15''$, or 0·005 inch.

The intervals of these lines from their mean as at present adopted were found from twenty-seven transits of close circumpolar stars taken by eye and ear in the summer and autumn of 1901.

The transits observed were : B.A.C. 2320, two ; λ *Ursæ Minoris*, three ; B.A.C. 4165, six ; B.A.C. 8213, six ; 51 *Cephei*, two ; δ *Ursæ Minoris*, three ; α *Ursæ Minoris*, two. They were reduced by the method described by Mr. Chandler, and all observations were treated as of equal weight. The adopted results are as follows. The sign refers to a transit east, and must be reversed for a transit west.

Wire.	Interval from Mean.	Wire.	Interval from Mean.	Wire.	Interval from Mean.	Wire.	Interval from Mean.	Wire.	Interval from Mean.
	′		′		″		″		″
0	−332·52								
1	223·25	6	−125·60	11	−27·70	16	+ 68·21	21	+165·59
2	208·69	7	112·33	12	13·55	17	82·22	22	181·25
3	194·88	8	98·01	13	− 0·66	18	96·47	23	194·48
4	180·86	9	82·70	14	+ 14·34	19	113·36	24	208·85
5	−166·71	10	− 68·94	15	+26·85	20	+127·89	25	223·86
								26	+334·86

For the purposes of a comparison, which is explained below, I have taken out the errors of the six transits of B.A.C. 4165 from their own mean, and they are as below:—

Accidental Errors of Transits of B.A.C. 4165 (+88°

Wire.	0	1	2	3	4	5	6	7	8	9	10	11	
1901.	″	″	″	″	″	″	″	″	″	″	″	″	
July 3	−0·1	+0·7	−0·1	+0·5	−0·2	−0·1	−0·5	−0·1	−0·3	+0·5	+0·2	+0·1	(
4	+0·5	+0·5	0·0	+0·1	+0·2	+0·5	+0·5	+0·7	+0·7	+0·1	+0·1	−0·3	.
15	+0·7	+1·0	+1·0	+0·2	+0·5	+0·5	+0·6	+0·5	+0·3	+0·4	+0·6	0·0	−(
20	+0·6	0·0	0·0	+0·5	+0·8	0·0	+0·5	0·0	+0·2	+0·3	0·0	0·0	+(
29	0·0	+0·2	+0·7	+0·3	+0·1	+0·6	−0·2	+0·2	+0·5	+0·1	+0·3	+0·6	+(
Aug. 2	−1·5	−2·2	−1·7	−1·6	−1·3	−1·3	−1·1	−1·3	−1·5	−1·4	−1·2	−0·4	−(

Probable error of a si

Accidental Errors of Tra

α Corc

Wire.	1	2	3	4	5	6	7	8	9	10	11	1
1902	″	″	″	″	″	″	″	″	″	″	″	
June 26	−0·2	−0·6	−0·7	+0·5	+0·1	−0·6	+0·7	−0·1	+0·2	0·0	−0·4	−1
,, 27	−0·4	+0·7	−0·1	0·0	+0·2	−0·3	−0·4	+0·8	0·0	−0·9	0·0	+(
,, 30	−1·0	+0·7	+0·6	+0·2	+0·3	0·0	−0·4	+0·3	+0·2	−0·4	+0·6	+
July 1	+0·3	−0·6	−0·1	−0·4	−0·7	+0·6	+0·8	−0·8	+0·2	+0·3	+0·1	−(
Aug. 23	+1·3	−0·1	+0·1	−0·4	+0·2	+0·1	−0·6	−0·4	−0·4	+0·9	−0·5	+(

Probable error for a sin

The column "p.e." is the probable error of a single observation, viz. the square root of the mean of the squares of the residuals opposite which it stands, multiplied by 0·6745.

Taking the whole of the observations (156) together, the probable error of a single observation is $\pm 0''\cdot437$.

I have remarked above that the correction for inclination of the wires to the horizontal has been treated as zero. This was done because there was no material for finding it. But when a considerable body of transits has been taken, the details of these if analysed will show what correction should be allowed. At the same time such an analysis offers a searching test of the accuracy of the observations themselves, and of the justice of the assumption that stars of all declinations determine zenith distance, *i.e.* the collimation constant with equal precision. For these reasons I have determined the wire intervals separately from the detailed transits of several stars of different declinations, each of which had been observed five times or more on one side of the meridian. I will give the wire intervals determined as a mean from each star below, but will now schedule on the same plan as above the excess of the individual observed wire interval over the mean from all the transits of that star, and derive the probable error in zenith distance of a single transit at each declination.

Excesses, Observed minus Mean.

14	15	16	17	18	19	20	21	22	23	24	25	26	p.e.
+0″·5	0″·0	+0″·1	−0″·1	0″·0	+0″·6	−0″·4	−0″·8	−0″·4	−0″·5	−0″·4	0″·0	−0″·2	±0″·25
−0·3	0·0	+0·3	−0·2	+0·4	+0·1	−0·8	−0·8	0·0	−0·4	0·0	0·0	0·0	0·26
−0·3	−0·2	−0·8	−0·6	−0·3	+0·4	−0·3	−0·4	+0·1	−0·8	0·0	+0·2	0·0	0·37
−0·4	−0·3	0·0	+0·2	−0·1	−0·6	0·0	−0·5	−0·5	0·0	+0·4	−0·1	+0·1	0·23
+0·8	+0·8	+0·2	+0·3	−0·1	−0·4	+0·3	+0·2	−1·1	−0·2	...	...	...	0·34
−0·2	−0·2	+0·1	+0·4	+0·2	0·0	+1·1	+2·4	+2·0	+2·6	...	...	...	0·84

...tion ±0″·437.

Excesses, Observed − Mean.

7° 3′.

14	15	16	17	18	19	20	21	22	23	24	25	p.e.
−0″·6	−1″·2	+0″·7	−0″·1	+0″·2	−0″·3	+0″·3	+1″·1	+0″·3	...	...	...	±0″·39
−0·1	+1·3	+0·1	−0·5	0·0	+0·5	+0·2	+0·4	+0·2	−0·1	−0·4	−0·2	0·30
0·0	+0·5	+0·7	+1·0	−0·3	−0·3	−0·6	−1·0	−0·1	−0·7	−0·2	+0·2	0·37
+0·2	+0·7	+0·6	−0·4	−0·1	+0·4	+0·3	−0·7	−0·4	+0·7	+0·5	0·0	0·34
+0·6	−1·1	−1·9	...	...	...	...	...	...	...	...	...	0·53

...tion ±0″·382.

ζ Pers

	1	2	3	4	5	6	7	8	9	10	11
1902	″	″	″	″	″	″	″	″	″	″	″
Oct. 20	−0·9	+0·3	−1·4	−0·5	−1·2	+0·3	+0·7	+0·6	−1·1	+0·4	−1·9
,, 30	0·0	−0·6	+0·3	0·0	+0·1	+0·3	+1·2	−0·1	+0·1	−0·1	+0·1
Nov. 7	+0·1	−0·4	−0·1	−0·6	−0·1	+0·7	−0·8	−0·7	−0·3	−0·2	+0·5
,, 10	+0·4	−0·5	+0·5	−0·2	+0·3	−0·3	+0·9	−0·5	−0·7	−0·7	0·0
,, 12	−0·6	+0·2	+0·8	+0·4	+0·2	−1·6	−0·7	+0·3	+1·3	0·0	+0·2
,, 17	−0·3	+1·3	+0·5	−0·4	+0·7	−0·3	−0·5	−0·4	+0·7	+0·2	+0·2
Dec. 15	+1·5	−0·3	−0·4	+1·0	+0·3	+0·6	−0·6	+0·5	0·0	+0·4	+0·8

Probable error for a

η A

	1	2	3	4	5	6	7	8	9	10	11
1902	″	″	″	″	″	″	″	″	″	″	″
Oct. 20	−0·3	+0·1	+1·1	+0·5	−0·2	−0·5	+0·5	+0·3	−0·5	+0·4	+0·4
,, 30	−1·2	−0·3	+0·7	+0·6	+0·4	+0·4	+0·4	+0·1	−1·3	+0·8	−0·7
Nov. 7	0·0	+0·9	−0·8	−1·7	+0·9	+0·1	−1·1	−0·5	+3·3	+0·1	−0·2
,, 10	0·0	0·0	−0·2	−0·2	+0·7	−1·0	−0·4	+0·3	+0·4	−2·2	−0·7
,, 17	+1·5	−0·1	−0·2	+0·2	−1·4	+0·2	−0·4	−0·6	0·0	+0·5	+0·9
,, 21	...	−0·6	−0·7	+0·5	−0·2	+0·6	+0·8	+0·9	0·0	+0·4	+0·2

Probable error for a

θ Boöt

	1	2	3	4	5	6	7	8	9	10	11
1902	″	″	″	″	″	″	″	″	″	″	′
Mar. 10	−0·4	−0·2	+0·3	+0·4	−0·1	+0·3	+0·1	−0·2	−0·6	−0·1	0·0
,, 17	−0·1	+0·3	+1·4	−0·4	−0·2	−0·1	−0·5	+1·7	−0·5	+0·6	−0·5
,, 22	+0·1	−1·2	+0·1	+0·9	+0·3	+0·8	−0·2	−0·7	+0·2	0·0	−0·3
April 2	+0·5	+0·6	−2·5	−0·4	−0·5	−0·9	+0·4	−1·2	+0·6	+0·3	−0·7
,, 4	−0·1	+0·6	+0·9	−0·4	+0·6	0·0	+0·3	+0·5	+0·5	−0·8	+1·4

Probable error for a

36′.

	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
7	−0″·5	+0″·3	+0″·3	−0″·2	+0″·6	−0″·2	−0″·4	+1″·4	−0″·4	−0′·3	−0″·1	0″·0	±0″·66
4	−1·4	0·0	−0·3	+0·7	+0·5	−1·1	−0·1	+0·5	+0·6	+1·0	+1·1	−0·5	0·47
2	−0·2	+0·8	+0·6	+0·7	−0·1	+0·8	+0·3	−0·7	−1·0	+0·2	−0·7	−0·7	0·40
2	+0·5	+0·8	+0·8	+0·7	−0·6	+1·5	+0·4	−0·7	−0·4	...	−0·4	−0·3	0·42
7	+1·1	−1·2	−0·5	−0·7	−1·0	+0·2	0·0	0·0	+0·9	−1·1	+0·7	+1·2	0·53
2	+0·6	−0·5	−0·6	−0·9	+0·3	−1·0	−0·2	+0·2	+0·6	+0·2	+0·3	+0·5	0·41
2	−0·3	−0·4	−0·3	−0·2	+0·2	0·0	0·0	−0·6	−0·5	0·0	−1·2	−0·5	0·38

ation ±0″·475.

° 6′.

	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
5	+0″·8	−0″·8	−0′·5	+0″·2	−0″·1	−0″·9	+0″·1	−1″·0	+1″·0	−0″·3	+0″·3	−0″·2	±0″·37
8	−2·0	+1·3	+1·3	−0·9	−0·1	+1·3	−0·1	+1·0	−1·1	+0·6	+0·1	−0·3	0·59
5	+1·1	+0·5	+1·0	−1·0	+0·9	−1·1	−0·4	+0·6	−0·9	−0·9	+0·3	−0·3	0·68
4	−1·2	−0·6	+0·9	+1·1	+0·2	+0·5	+0·1	+0·2	0·0	0·0	+0·4	+0·7	0·49
1	+0·6	−0·2	−0·8	+0·5	0·0	+0·2	+0·3	−0·6	+0·7	−0·2	−0·8	+0·6	0·44
0	+0·8	−0·4	−2·1	−0·2	−1·1	+0·2	0·0	0·0	+0·5	+0·5	−0·5	−0·5	0·45

ation ±0″·516

18′.

	14	15	16	17	18	19	20	21	22	23	24	25	p.e.
4	+0″·5	−0″·3	−0″·7	−0″·4	−0″·6	+0″·3	+0″·7	−0″·2	+1″·3	+0″·2	0″·0	0″·0	±0″·38
3	+0·5	−0·3	+0·2	0·0	−0·6	−0·9	+0·1	+0·7	+0·8	+0·1	−0·5	−0·9	0·43
1	−0·7	0·0	−0·5	+0·5	+0·8	+0·3	−0·9	−0·2	+0·6	+0·9	+0·1	−1·1	0·41
0	−0·4	+0·9	+1·1	0·0	−0·2	+1·2	+0·9	−0·5	−2·5	+0·1	+0·2	+1·4	0·66
0	−0·1	−0·4	+0·1	−0·1	+0·1	−0·9	−0·7	0·0	0·0	−1·4	+0·3	+0·6	0·43

vation ±0″·475.

α C

	1	2	3	4	5	6	7	8	9	10	11
1902	″	″	″	″	″	″	″	″	″	″	″
Oct. 20	−0·1	+0·4	−0·6	+0·4	+0·8	−0·1	−1·4	−0·9	+0·3	−1·8	+1·7
,, 30	−0·7	+0·5	+0·1	+1·7	−0·5	+0·6	+0·3	+0·6	−0·6	0·0	−0·3
Nov. 7	+0·6	+0·4	−0·6	+0·3	+1·2	−0·7	+0·4	+0·9	−0·3	+0·9	−0·1
,, 10	−0·1	−0·8	+1·3	−1·6	−1·0	+0·5	+0·8	−0·4	+1·1	0·0	−0·1
,, 17	0·0	−0·9	−0·1	−0·5	...	...	0·0	−1·3	−0·1	+2·0	−0·5
,, 21	+0·1	+0·4	−0·2	0·0	−0·5	−0·5	−0·1	+0·9	−0·1	−1·1	−0·6

Probable error for a

ϵ Dra

	1	2	3	4	5	6	7	8	9	10	11
1902	″	″	″	″	″	″	″	″	″	″	″
Oct. 20	+0·7	+1·0	+0·1	+0·1	+0·1	+0·3	−2·2	−0·9	+0·5	−1·3	+1·5
,, 21	+0·2	0·0	−0·9	+0·6	−0·2	−0·3	−0·2	−0·2	+0·1	−0·1	−0·3
,, 30	0·0	+0·1	−1·0	−0·9	−0·2	−1·4	+1·8	−0·7	+0·6	−1·3	−0·3
Nov. 7	−1·4	−0·8	+0·8	−0·2	−0·7	−0·1	0·0	+0·3	+1·0	−0·1	−0·5
,, 10	+0·7	+0·2	+0·3	0·0	−1·0	+0·2	+0·5	−0·3	−0·9	+0·9	+0·3
,, 12	−1·5	−0·4	+1·2	+0·8	+0·9	−0·1	−0·3	+0·2	−0·8	+0·1	+1·0
,, 21	+0·6	+0·4	+0·6	−0·2	0·0	+0·2	+0·1	+0·9	0·0	+0·4	−1·3
Dec. 15	+0·7	−0·4	−0·7	−0·4	+0·9	+1·1	+0·4	+0·5	−0·7	+1·4	−0·1

Probable error for a s

76 Dra

	1	2	3	4	5	6	7	8	9	10	11
1902	″	″	″	″	″	″	″	″	″	″	″
May 20 E.	−0·1	+1·0	+0·4	−0·9	−0·5	+0·2	−0·6	−0·2	...	...	+0·1
,, 23 E.	0·0	−1·2	+2·2	+0·5	+0·2	+1·2	+0·2	−0·1	+1·2	+0·4	+0·1
,, 28 E.	−0·3	−0·7	−0·5	0·0	−1·0	−0·6	+0·4	+1·3	−0·7	−0·5	+0·2
Nov. 17 W.	+0·3	+0·7	−1·0	−0·3	+1·5	−0·8	−0·2	−0·3	0·0	+0·1	−0·8
Nov. 21 W.	−0·1	+0·3	−0·9	+0·9	0·0	+0·2	+0·2	−0·6	−0·6	0·0	+0·4

Probable error for a s

In these errors there seems to me no tendency to systematic progression with the declination ; the large value found from the observations of *α Cephei* seems entirely due to two ill-judged transits as wires 23, 25 on November 7. I consider that these errors confirm the conclusion of § 3 on the standard form of equation, in which the collimation constant has always the same coefficient.

° 10′.

14	15	16	17	18	19	20	21	22	23	24	25	p.e.
−0″·3	−0″·4	−0″·4	+0″·2	−0″·8	+1″·2	−0″·5	+0″·1	−0″·1	+1″·1	−1″·4	+2″·2	±0″·63
−0·8	−0·1	−0·3	−0·4	−0·4	+0·1	−0·9	−0·2	+0·2	+0·7	−1·1	+0·7	0·41
−0·7	+0·5	+1·4	−1·0	−1·2	−0·7	+0·9	+0·9	−0·4	−3·0	+1·3	−2·9	0·78
+1·4	+0·3	−0·9	+0·8	+0·3	−0·4	−0·7	−0·5	−0·3	−0·3	+1·0	−0·2	0·51
−0·5	+0·5	+0·4	+0·4	+1·9	−0·2	−0·3	−0·8	+0·2	+0·8	+0·8	+0·3	0·51
+0·8	−0·7	...	−0·1	+0·1	...	+1·4	+0·3	0·0	+0·5	−0·9	−0·1	0·37

tion ±0″·562.

° 1′.

14	15	16	17	18	19	20	21	22	23	24	25	p.e.
−0″·5	−1″·0	+0″·2	−0″·5	+0″·3	−1″·0	−0″·1	+0″·7	+0″·5	+0″·1	+0″·2	+0″·9	±0″·54
+0·5	+1·2	+0·1	−0·5	−0·2	−0·1	+0·9	+0·4	−1·1	−0·2	−0·3	−0·3	0·34
+0·4	−0·1	+0·3	−0·3	+0·5	−0·6	+0·3	+0·7	+0·6	+1·1	+0·3	+0·1	0·49
+0·2	−1·3	+0·7	+1·1	+0·8	+0·7	+0·2	+0·1	−0·1	−0·5	0·0	−0·4	0·45
−0·2	+0·6	−0·2	+0·7	−0·5	−0·4	−0·1	−0·5	+0·6	−0·5	+0·2	−1·0	0·36
−0·7	+0·7	−0·4	0·0	−0·5	+0·7	−0·7	−1·1	+0·3	−0·3	−0·8	+1·0	0·53
+0·1	−0·7	−0·8	−0·1	0·0	+0·4	−0·5	−0·6	−0·1	+0·7	+0·5	−0·2	0·35
0·0	+0·5	−0·1	−0·7	−0·3	+0·1	−0·3	0·0	−0·4	−0·5	+0·2	0·0	0·38

tion ±0″·436.

+82° 10′.

14	15	16	17	18	19	20	21	22	23	24	25	p.e.
−0″·6	+1″·0	+0″·5	−0″·5	+0″·2	−0″·2	+0″·9	+0″·1	+0″·2	−0″·5	−0″·6	+0″·2	±0″·36
−0·2	−0·6	−1·1	−0·3	−1·0	+0·8	−0·8	+0·5	−0·5	−0·6	+0·3	+0·2	0·51
+0·5	−0·3	0·0	+1·0	+0·5	0·0	+1·9	−0·7	+0·4	+0·3	−0·3	−0·3	0·45
+0·5	−0·3	+0·7	+0·1	−0·1	−0·3	−0·6	−0·3	+0·3	+1·2	+0·7	−0·3	0·45
−0·3	0·0	0·0	−0·1	+0·2	−0·2	−1·5	+0·5	−0·2	−0·6	...	...	0·34

tion ±0″·429.

If all the observations are collected in one group—1027 in number—the probable error of a single observation emerges at ±0″·473, and the probable error of the mean of twenty-five such observations at ±0″·097. This error covers the error of the chronograph and of the inconsistencies of the observer during the transit. Errors which it does not cover are fluctuations in personality of the observer between one transit and another, fluctua-

tions if any in the clock, anomalous refraction, anomalous changes in the collimation constant. It will appear below that these errors in all amount to about four times the above amount.

I shall now give in the following table the wire intervals as derived from the different stars :—

Observed Wire Intervals from Different Stars minus Intervals adopted from Polar Stars (p. 360).

	α Coronæ W. +27° 3′.	ζ Persei E. +31° 36′.	η Aurigæ E. +41° 6′.	θ Boötis E. +52° 18′.	α Cephei W. +62° 10′.	ε Draconis W. +70° 1′.	76 Draconis. +82° 10′.
	″	″	″	″	″	″	″
1	−0·15	−2·02	−1·31	−0·05	−0·08	−0·65	−0·29
2	+0·91	−1·71	−0·61	+0·01	−0·11	−0·10	+0·11
3	+0·44	−1·89	−1·24	+0·32	+0·26	−0·17	+0·32
4	+0·94	−1·88	−1·16	−0·32	−0·19	+0·03	+0·10
5	+0·33	−1·65	−0·86	+0·33	+1·21	+0·28	+0·25
6	+0·76	−0·94	−1·13	+0·02	+0·66	−0·21	+0·04
7	+0·25	−1·44	−0·30	+0·45	+0·43	−0·06	−0·17
8	+0·47	−0·73	−0·34	−0·47	−0·12	−0·52	+0·33
9	−0·06	−0·90	−0·35	+0·04	+0·55	+0·07	+0·47
10	+0·32	+0·64	−0·06	+0·84	−0·26	+0·06	−0·16
11	+0·06	−0·11	+0·28	+0·08	+0·42	+0·24	+0·10
12	+0·41	+0·87	−0·48	−0·03	−0·10	+0·39	+0·41
13	−0·56	−0·24	−0·54	+0·02	+0·08	+0·38	−0·60
14	−0·12	+0·03	+0·08	+0·32	−0·36	−0·16	+0·54
15	−0·41	+0·72	+0·52	+0·13	+0·27	+0·14	+0·11
16	−0·57	+0·69	+0·96	+0·33	+0·43	−0·03	+0·02
17	+0·18	+0·29	+0·23	−0·52	+0·26	+0·04	−0·18
18	−0·02	+1·12	+0·60	+0·11	+0·11	+0·04	+0·19
19	−0·56	+1·47	+1·37	−0·16	−0·06	+0·31	+0·46
20	+0·24	+0·71	+0·44	−0·47	−0·31	−0·03	+0·59
21	−0·94	+1·32	+0·74	−0·23	−0·72	−0·03	−0·17
22	−0·65	+0·82	+0·18	−0·81	−0·92	−0·11	−0·81
23	−0·91	+1·12	+0·77	−0·10	−0·71	−0·19	−0·12
24	−0·48	+1·31	+1·32	+0·17	+0·10	−0·01	−1·32
25	−0·36	+2·60	+1·24	+0·74	−0·06	+0·85	−0·21

It is clear that a large part of these quantities are accidental errors, for the probable error of a single entry is from ±0″·20 to ±0″·30. But if we seek their systematic features, we must write in the notation of § 2.

$$\text{Tabulated quantity} = \Delta\zeta_r \mp \cot t_0\, \zeta_r\gamma_r'' \sin 1''$$

where the lower sign refers to a transit east, and $\Delta\zeta_r$ is a correction to the adopted wire interval after the rth wire at its middle point, and γ_r is the inclination of that wire, reckoned positive when the west end is lowest. If we add the equations for the three east stars, and those of the three west stars for each wire, and solve for $\Delta\zeta_r$, and $\zeta_r\gamma_r \sin 1''$, we get the results of the following table. I have included in it the unexplained residuals of the different stars (Observed − Computed).

Inclinations of the Separate Wires deduced from Table (p. 366).

	$\Delta\zeta_r$.	$\zeta_r\gamma_r''$ $\sin 1''$.	α Coronæ W.	ζ Pers. E.	η Aur. E.	θ Boöt. E.	α Ceph. W.	ε Drac. W.	76 Drac.
	″	″	″	″	″	″	″	″	″
1	−0·68	+0·50	−0·34	−0·69	−0·21	+0·91	+0·41	−0·10	−0·39
2	−·24	+·60	+·11	−·70	+·13	+·58	−·09	−·02	−·35
3	−·34	+·66	−·36	−·70	−·35	+1·02	+·36	·00	−·66
4	−·38	+·82	−·10	−·44	−·09	+·51	−·11	+·20	−·48
5	−·02	+·79	−1·02	−·61	−·18	+·78	+·94	+·09	−·27
6	−·10	+·65	−·26	·00	−·48	+·48	+·52	−·28	−·14
7	−·09	+·38	−·32	−·86	+·11	+·75	+·38	−·07	+·08
8	−·27	+·27	+·27	−·11	+·16	−·05	−·05	−·32	−·60
9	−·09	+·35	−·58	−·36	+·03	+·32	+·51	+·07	−·56
10	+·25	−·26	+·52	+·05	−·53	+·45	−·41	−·12	+·41
11	+·17	+·09	−·27	−·16	+·19	−·04	+·22	+·05	+·07
12	+·18	+·07	+·11	+·78	−·60	−·17	−·31	+·19	−·23
13	−·13	+·13	−·65	+·06	−·30	+·22	+·16	−·48	+·47
14	−·05	−·21	+·29	−·19	−·05	+·25	−·23	−·06	−·59
15	+·21	−·27	−·15	+·16	+·54	−·23	+·09	·00	+·10
16	+·28	−·43	−·11	−·14	+·42	−·19	+·31	−·01	+·26
17	+·09	+·10	−·08	+·33	+·22	−·55	+·13	−·24	+·27
18	+·31	−·34	+·26	+·37	·00	−·39	−·07	−·18	+·12
19	+·37	−·59	+·09	+·34	+·50	−·85	−·21	+·09	−·09
20	+·09	−·16	+·43	+·41	+·22	−·65	−·34	−·08	−·50
21	−·02	−·70	+·29	+·44	+·17	−·60	−·44	+·17	+·15
22	−·23	−·37	+·22	+·57	+·10	−·78	−·55	+·22	+·58
23	−·04	−·71	+·36	+·24	+·21	−·45	−·41	+·03	+·08
24	+·36	−·63	+·25	+·14	+·43	−·54	−·03	−·21	+1·68
25	+·79	−·82	+·27	+·75	−·24	−·50	−·55	+·27	+1·00

The quantities $\Delta\zeta$ indicate a slight but clear tendency to estimate the intervals less by eye and ear—from which they were

adopted—than by chronograph. Derived from the wires 1–12 this tendency increases each interval on the average 0″·13; derived from 14–25 the amount is 0″·16.

The quantities $\zeta_r\gamma_r$ show that besides minor inequalities of the inclinations of the wires to one another the whole plate is slightly tilted. Deriving the amount from the first, second, fourth, fifth tallies successively the inclination of the mean wire to the horizontal appears at 710″, 584″, 649″, 682″ respectively, or, taking all together, 670″, the west end standing highest.

§ 7. *Collected Instrumental Constants.*

In any group of observations, before any information can be derived about the places of the stars observed, it is necessary to determine the collimation constant of the instrument, z, and the clock error. In addition to these I have determined $\Delta\phi$ the latitude correction whenever there were ten or more stars to deal with, and in some cases when there were fewer. In the final form of discussion explained above the quantity called 10z is

$$10z = \tfrac{1}{25}\Sigma_{25}(z_r - r_r) + (1 - \sin\bar{\delta})\sec^2\phi_0\Delta\phi$$

where z_r is the elevation of the rth wire of the observing tallies above the true colatitude circle, and r_r is the refraction at apparent Z.D. $90° - (\phi_0 + z_r)$, at mean state of atmosphere, barometer 30·0 in., thermometer 50°·0, as adopted in the Greenwich Table. ϕ_0 is taken at 54° 46′ 6″·2, and $\bar{\delta}$ at 52° 2′. Hence the values of 10z are comparable from night to night, except for latitude variation; but this is quite insignificant in comparison with other unexplained changes in 10z.

The true latitude at date is

$$\phi_0 + \Delta\phi = 54° 46′ 6″·2 + \Delta\phi$$

The following are the results obtained since 1901 October 26. The column "mean v" must not be taken too rigorously as a measure of the exactness of the observing, as it refers to different groups of stars on different nights. Up to 1901 Nov. 15 a method of reduction and discussion substantially the same as Mr. Chandler's was adopted, the observations being taken of equal weight in respect to the clock correction; but they were combined by means of Least Squares. After that date the method was the one explained in § 3, but curvature and refraction were first allowed for after 1901 December 7.

Latitude and Collimation.

Date. 1901.	No. of Stars Observed.	Mean v.	$\Delta\phi$.	$i\sigma$.	$i\Delta z$.
* Oct. 26	16	...	−0″·18	− 8″·75	...
* Nov. 1	9	...	0·60	− 10·28	...
Nov. 1	8	...	−1·78	− 11·25	...
* Nov. 2	15	...	−1·08	− 10·67	...
Nov. 4	8	...	−1·64	− 9·98	...
Nov. 5	15	...	−0·71	− 12·47	..
Nov. 7	13	...	0·00	− 6·93	...
* Nov 14	11	...	−0·94	− 10·96	...
Nov. 14	13	...	−0·58	− 11·77	...
* Nov. 15	16	...	−0·60	− 14·44	...
Nov. 15	11	...	−0·39	− 9·52	...
a Nov. 23	19	±·060	−0·76	− 12·25	...
Nov. 27	8	±·026	−0·32	− 9·04	...
Dec. 7	9	±·209	+3·19	− 12·41	...
b * Dec. 27	13	±·052	−0·93	− 8·49	...
Dec. 27	8	±·028	+0·08	− 10·02	...
1902. Jan. 29	11	±·077	−1·28	− 8·05	...
Jan. 30	16	±·068	−1·33	− 8·22	...
Jan. 31	12	±·038	−0·11	− 8·65	...
Feb. 17	12	±·070	+0·07	− 12·39	...
c Feb. 28	16	±·070	+0·46	− 11·21	...
Mar. 10	16	±·044	+0·32	+ 1·31	...
Mar. 17	12	±·034	+0·37	+ 3·85	...
d Mar. 22	9	±·056	...	− 1·64	...
d Mar. 22	5	±·034	...	+ 1·34	...
* *e* Mar. 25	10	±·058	−0·31	+ 2·09	...
* *f* Mar. 29	6	...	...	+ 1·27	...
Apr. 2	16	±·044	−0·13	+ 1·23	..
d Apr. 4	7	±·049	...	+ 1·58	...
d Apr. 4	6	±·073	...	+ 0·03	...
g Apr. 9	10	±·058	+0·31	+ 0·19	...
* Apr. 10	20	±·133	+0·13	+ 5·49	...
* Apr. 17	13	±·075	+0·70	+ 4·28	...
Apr. 23	6	±·062	...	+ 3·94	...

Date. 1902.	No. of Stars Observed.	Mean v.	$\Delta\phi$.	$10z$.	$10\Delta z$.
			″	″	″
Apr. 26	7	±·043	...	+ 2·77	...
May 1	14	±·055	−0·05	+ 1·24	...
May 2	8	±·054	−0·49	+ 1·82	...
h May 8	23	±·076	(−0·43)	(+ 1·45)	...
h May 8	12	±·059	(−0·48)	(+ 1·06)	...
h May 8	11	±·070	(−0·03)	(+ 1·92)	...
h May 8	23	±·050	−0·46	+ 1·42	+0·50
j May 20	10	±·051	−0·08	+ 14·72	...
May 23	16	±·045	−0·48	+ 15·46	...
May 28	15	±·043	−0·04	+ 9·57	+0·93
j June 26	13	±·036	−0·06	− 21·79	...
June 27	14	±·093	+0·74	− 18·53	...
June 30	19	±·045	+0·43	− 17·11	...
July 1	22	±·037	−0·06	− 23·70	−0·52
k Aug. 23	14	±·058	+0·70	+194·35	+1·15
Sept. 8	12	±·054	−0·05	+193·33	0·00
Sept. 16	10	±·062	+1·76	+191·21	0·00
c Sept. 18	10	±·052	0·00	+ 3·08	0·00
Sept. 24	24	±·054	−0·61	+ 3·33	0·00
Oct. 8	9	±·067	−2·30	+ 3·24	0·00
Oct. 11	17	±·082	−0·10	+ 2·67	0·00
Oct. 20	24	±·074	−0·92	− 6·14	+1·36
Oct. 21	12	±·049	−0·02	− 6·47	+2·07
Oct. 30	18	±·058	+0·05	− 7·73	0·00
Nov. 1	13	±·058	−1·70	− 9·23	0·00
Nov. 7	15	±·080	−0·89	− 6·69	+2·00
Nov. 10	15	±·046	−0·63	− 8·00	+1·60
Nov. 12	11	±·047	+0·23	− 6·03	+0·78
Nov. 17	21	±·048	−0·88	− 7·62	−0·16
Nov. 21	14	±·060	−0·73	− 11·00	+0·82
l Dec. 15	21	±·110	−0·30	− 6·57	+0·60

Notes to above Table.

* Observer, R.A.S. *a* New method of discussion first used. *b* Curvature and change of refraction first allowed for. *c* Collimation changed by hand. *d* This group, showing sign of change in z, was solved in two parts. *e* Signs of change in z being noticed among the latter observations only 1–10 were

brought into solution and 11–16 discarded. *f* Summary discussion only, no residuals adopted. *g* Four observations by R.A.S. combined with eight by F.C.H.C. allowing for personality $S - C = -0^s{\cdot}110$. *h* Signs of change in z being noticed this group was solved three ways: first, as usual, allowing for no change in z; second, in two groups, supposing z constant in each; and third, in one group, applying to each observation an allowance in proportion to the change indicated by the solution in two groups. The last solution was adopted. *j* Collimation constant disturbed. *k* Collimation constant disturbed by removal of dew-cap for new wind screen. *l* Observations condemned owing to erratic changes in z.

Remarking first upon the determinations of latitude, it must be remembered that the observations were in no way specially directed towards finding this quantity; on the contrary, transits at small hour-angles, which are specially required, were rather avoided at the present stage of the inquiry, and in consequence a difference of $1''$ in $\Delta\phi$ would affect very few of the stars observed by as much as $0^s{\cdot}1$ in a transit. Remembering this, it is not surprising that, for example, on 1902 October 8 from nine stars the value $\Delta\phi = -2''{\cdot}30$ was deduced. Besides, there seems some tendency for the same value to reproduce itself for some time, and then to change somewhat suddenly to another. This may be due to the observations in the neighbourhood of any given date depending upon much the same group of stars, and may show that the adopted star places have not been quite accurate enough to work from.

The results do not justify elaborate discussion, but grouped together they do not seem altogether random. To unite them we must take account of the weight with which each appears, and after 1901 November 23 this is very easily extracted from my solution, where $10x = \Delta\phi$ is the last unknown in order, and therefore the first to be evaluated in the normal equations. I omit the observations of 1901 December 7 and 1902 April 10, which the residuals indicate to be a failure from some cause I do not know. Dividing the rest into convenient groups :—

Extreme Dates.	No. of Nights.	$\Delta\phi$.	Weight.
1901 Nov. 23...1902 Jan. 31	7	$-0''{\cdot}74$	15·4
1902 Feb. 17... Apr. 17	8	$+0''{\cdot}20$	25·6
May 1... July 1	10	$-0''{\cdot}03$	36·0
Aug. 23... Oct. 21	9	$-0''{\cdot}18$	34·4
Oct. 30... Dec. 15	8	$-0''{\cdot}58$	35·3
1901 Nov. 23 ...1902 Apr. 17	15	$-0''{\cdot}15$	41·0
1902 May 1... Dec. 15	27	$-0''{\cdot}26$	105·7
The whole	42	$-0''{\cdot}23$	146·7

The adopted latitude of Durham—54° 46′ 6″·2—was deter-

mined in 1843, and of course refers to the old transit circle which stands 79 feet to the north of the centre of the almucantar pier.

The cardinal question of the almucantar may be said to be the behaviour of the collimation constant z upon any one night, how much it changes systematically in the course of the night, and how much it changes erratically from star to star.

I began by assuming z to be constant, but it soon became clear that this could not be strictly maintained, from the occasions when both myself and Mr. Carpenter had observed on the same night. For instance, 1901 November 1 shows a change from $-10''\cdot28$ to $-11''\cdot25$ in $3^h\,6^m$; November 14, from $-10''\cdot96$ to $11''\cdot77$ in $3^h\,33^m$; November 15, for $-14''\cdot44$ to $-9''\cdot52$ in $3^h\,33^m$—an anomalously large change—and December 27, from $-8''\cdot49$ to $-10''\cdot02$ in $3^h\,36^m$. But we could not be sure how much of this might be a personal element. On 1902 March 22 a series of 14 stars, taken by Mr. Carpenter, showed suggestions of an erratic change in z, in the middle, and was consequently solved in two groups, the latitude correction being ignored; the first 9 stars gave $10z = -1''\cdot64$, the last 5, $10z = +1''\cdot34$. On April 4 a similar phenomenon was noticed.

Then, for a number of nights, I took out the individual z as indicated by each observation, and the same as it would have been shown if I had allowed for the residual of that individual star as determined from previous transits. The results showed in a marked way the improvement of the values of individual z's in point of consistency, and at the same time the consistency of its residuals; they also show that, though in some cases there may be erratic changes in z, there may also be a well-marked gradual change that could and should be allowed for. A series of 23 stars on May 8 gave good material for further examination of this point, especially on the effect of alternative methods of solution upon the residuals determined for particular stars. They were first solved in a single group, assuming z to be constant. The resulting instrumental corrections were $10z = +1''\cdot45$, $\Delta\phi = -0''\cdot43$; clock correction at 0^h S.T. $= +26^s\cdot189$. The individual values of $10z$ were found, and were marked on a chart, the values of $10z$ being relieved of the residuals belonging to each particular star as determined by previous transits, and they indicated clearly enough that $10z$ increased at a uniform rate of about $+0''\cdot50$ per hour; and that the value of $10z$ given by the solution corresponds closely with that belonging to the middle of the observations. The first 12 stars and the next 11 were solved in the same way, assuming z constant in each. The results were respectively—first 12: clock correction, $+26^s\cdot188$, $10z = +1''\cdot06$, $\Delta\phi = -0''\cdot48$; second 11: clock correction $+26^s\cdot214$, $10z = +1''\cdot92$, $\Delta\phi = -0''\cdot03$—showing that $10z$ increased $+0''\cdot86$ in $1^h\,40^m$, if we take the two values to belong to the middle times of the two groups. Lastly, the 23 were solved in one group, after correcting n for each star for the

change in $10z$ at the rate of $+0''\cdot50$ per hour. The results were: clock correction $+26^s\cdot198$, $10z = +1''\cdot42$, $\Delta\phi = -0''\cdot46$. The last method was laborious, since it involved two solutions of the same equations—the first to find the change in $10z$, and the second after this change had been removed from the values of n employed. It was undertaken in order to see what effect it had upon the residuals, and the conclusion was that exactly the same residuals were shown by applying directly to the residuals that emerged, on the supposition that $10z$ was constant, the corrections that belonged to the estimated change in $10z$. The average difference was $\pm\cdot003$, and nowhere did it exceed $\cdot007$. Hence it is clear that where a change in $10z$ is perceived after solution it is perfectly safe to clear its effect from v by the method of § 3.

It is clear, at the same time, that the clock correction and the latitude correction are not sensibly modified by this procedure.

As these changes in z are of the utmost importance in the theory of the instrument—first in order to estimate reliably their amount and to allow for it, and then, if possible, to trace their cause and remove them—I have added below full detail with regard to the unexplained or accidental portion of $10z$ as it appears in the individual transits from 1901 December 27 to 1902 December 15.

Consider the equations

$$\mp z_i + ay \mp bx + n = 0$$
$$\mp z_a + ay \mp bx + n = v$$

then z_i is the indicated value of z from an individual observation, y, x being supposed known and n given; and z_a is the adopted value of z for that observation arising from the mean value given by solution, and the estimated hourly change in z. Let v_0 be the true value which v should have, that is, the value which would give the true (unknown) coordinates of the star; then if we put

$$\mp z_b + ay \mp bx + n = v_0$$

the quantity z_b would give the true collimation of the instrument at the true time of observation, and may be conveniently examined by means of

$$z_b - z_a = \pm(v - v_0)$$

where the upper sign refers to a transit east. This quantity may be considered as a sum of the faults of the instrument, the observer, and the method of discussion; if it shows a systematic element, the method of discussion is in fault, as, for example, a uniform rate of increase or decrease could be removed by adopting differently Δz.

Of unsystematic elements, if c'' measures what is erratic instrumentally, whether due to anomalous refraction, if any, or

to failure of the instrument to regain its former Z.D. after disturbance by motion in azimuth for setting, and if e^s denotes what is erratic in the observer's record, we may take

$$z_b - z_a = \tfrac{1}{10}c'' + a \times e^s$$

where a is the same coefficient as is used above.

In making out the following table v_o has been taken from the mean of the observations of that star in all cases where there were as many as three observations ; when there were only one or two it has been taken at zero. The latter cases are marked by an asterisk. The stars are indicated by the reference numbers attached to them in the list of collected residuals for individual stars, § 8 ; thus the first star, 24 E., denotes a transit east of α *Persei*. In the earlier observations several stars were observed only once, and were not included when the list was made up. These have no reference number attached to them, but merely the letter E. or W.

Unexplained Residuals $(z_b - z_a)$ *in Individual Observations from* 1901 *December* 27 *to* 1902 *December* 15.

1901 Dec. 27.	Dec. 27—*cont.*	Jan. 30—*cont.*	Jan. 31—*cont.*
24 E. − ·06*	15 W. + ·04*	E. − ·04*	21 W. − ·03
128 W. ·00*	p.e. ± ·020	54 E. − ·08*	W. − ·01*
140 W. − ·01*		E. + ·10*	70 E. − ·05*
E. + ·04*	1902 Jan. 29.	12 W. + ·01*	73 E. ·00*
119 W. + ·01	W. ·00*	53 E. + ·07*	W. + ·07*
130 W. − ·04*	E. − ·10*	49 E. + ·05*	76 E. − ·05*
146 W. + ·13*	150 W. − ·11*	22 W. + ·05*	p.e. ± ·031
144 W. − ·08	W. − ·13*	63 E. − ·08*	
148 W. + ·02	E. + ·03*	21 W. − ·04	Feb. 17.
27 E. + ·02	E. + ·02*	18 W. − ·07*	21 W. + ·07
35 E. + ·04	E. + ·12*	W. − ·03*	18 W. + ·07*
38 E. − ·02	7 W. + ·08*	24 W. ·00*	W. + ·06*
33 E. − ·05	W. + ·13*	E. − ·08*	E. + ·10*
p.e. ± ·034	E. + ·05*	p.e. ± ·05 ;	E. + ·10*
	51 E. − ·08*		39 W. + ·03*
55 E. − ·02*	p.e. ± ·060	Jan. 31.	73 E. − ·09*
155 W. − ·04*		49 E. − ·07*	74 E. − ·09*
2 W. − ·01*		22 W. ·00*	76 E. − ·03*
17 W. − ·01*	Jan. 30.	27 W. ·00*	67 E. ·00*
48 E. + ·04*	E. + ·13*	58 E. + ·08*	36 W. − ·04
153 W. + ·03*	2 W. + ·13*	68 E. + ·03*	35 W. ·07
56 E. − ·03*	W. − ·12*	63 E. + ·05*	p.e. ± ·047

Feb. 28.

79 E. − ·15*
67 E. + ·08*
36 W. + ·04
35 W. − ·01
E. − ·15*
84 E. + ·07*
38 W. + ·02
42 W. − ·03
31 W. + ·01
75 E. + ·05
83 E. + ·03
46 W. + ·03
89 E. + ·04
80 E. + ·02
50 W. + ·02
W. − ·05*
p.e. ± ·045

Mar. 10.

35 W. + ·10
84 E. + ·13*
38 W. − ·04
42 W. − ·02
31 W. − ·01
75 E. − ·01
83 E − ·03
W. ·00*
46 W. + ·02
89 E. − ·02
80 E. − ·01
50 W. − ·02
W. − ·07*
94 E. - ·02
86 E. ·00
51 W. − ·03
p.e. ± ·032

Mar. 17.

75 E. ·00
83 E. + ·05
W. ·00*
46 W. − ·02
80 E. − ·10
50 W. + ·02
30 W. + ·02
53 W. − ·05*
94 E. − ·02
86 E. + ·01
51 W. − ·01
85 E. + ·06
p.e. ± ·028

Mar. 22

83 E. ·00
41 W. + ·10*
40 W. − ·01*
80 E. + ·05
50 W. + ·01
30 W. − ·03
86 E. − ·03
99 E. − ·02
85 E. + ·02
p.e. ± ·028

77 E. − ·05
101 E. + ·06
44 W. + ·02
60 W. + ·02
E. ·00*
p.e. ± ·025

Apr. 2.

30 W. + ·03
53 W. − ·01*
94 E. − ·01
86 E. ·00

Apr. 2—*cont.*

99 E. + ·10
77 E. + ·06
101 E. − ·01
44 W. + ·03
60 W. − ·01
104 E. − ·03
100 E. − ·03
61 W. + ·02
54 W. − ·01
82 E. − ·06
93 E. + ·02
92 E. + ·01
p.e. ± ·025

Apr. 4.

94 E. + ·04
86 E. + ·03
51 W. + ·03
85 E. + ·01
77 E. + ·01
101 E. − ·08
44 W. − ·06
p.e. ± ·030

60 W. − ·02
104 E. − ·01
100 E. ·00
61 W. ·00
54 W. + ·01
82 E. + ·06
p.e. ± ·018

Apr. 9.

24 W. + ·06*
43 W. + ·03*
36 W. − ·05
75 E. − ·03
83 E. − ·07

Apr. 9—*cont.*

34 W. + ·09*
46 W. − ·05
89 E. − ·02
80 E. + ·06
50 W − ·03
p.e. ± ·036

Apr. 17.

36 W. + ·06
35 W. ·00
78 E. + ·19*
64 E. − ·04*
38 W. + ·02
42 W. + ·05
31 W. + ·01
81 E. − ·08*
30 W. − ·01
48 W. − ·06*
99 E. − ·07
85 E. − ·03
101 E. + ·04
p.e. ± ·047

Apr. 23.

104 E. + ·04
100 E. + ·05
61 W. + ·02
54 W. ·00
82 E. − ·04
58 W. − ·05
p.e. ± ·026

Apr. 26.

85 E. − ·04
77 E. − ·03
101 E. ·00
44 W. + ·01

Apr. 26—*cont.*

106 E. + ·03*
104 E. + ·01
100 E. + ·05

p.e. ± ·020

May 1.

100 E. − ·07
61 W. + ·01
54 W. ·00
82 E. + ·02
58 W. − ·04
93 E. − ·01
92 E. + ·02
102 E. + ·06
88 E. + ·02
56 W. + ·02
96 E. − ·08*
115 E. − ·01*
111 E. + ·02*
59 W. + ·01

p.e. ± ·026

May 2.

58 W. + ·08
97 E. + ·02*
93 E. − ·01
92 E. − ·08
102 E. − ·06
88 E. ·00
56 W. − ·02
55 W. − ·03*

p.e. ± ·032

May 8.

44 W. + ·02
106 E. − ·01*
104 E. − ·01

May 8—*cont.*

100 E. + ·02
61 W. − ·03
54 W. − ·01
82 E. + ·01
92 E. + ·04
102 E. − ·01
88 E. − ·01
56 W. ·00
55 W. + ·03*
52 W. − ·17*
96 E. − ·09*
115 E. − ·04*
111 E. − ·02*
59 W. + ·01
65 W. + ·03*
113 E − ·01*
57 W. + ·06
105 E. + ·05*
110 E. + ·04
119 E. + ·04

p.e. ± ·033

May 20.

57 W. − ·05
110 E. − ·02
107 E. + ·02
70 W. + ·02
125 E. ·00
77 W. − ·10*
62 W. ·00
120 E. − ·05
132 E. − ·02
68 W. + ·08

p.e. ± ·032

May 23.

59 W. − ·02
65 W + ·14*

May 23—*cont.*

113 E. − ·01*
57 W. − ·01
110 E. − ·07
119 E. − ·04
107 E. + ·01
70 W. + ·01
125 E. + ·05
62 W. + ·01
120 E. + ·03
132 E. − ·01
68 W. − ·02
116 E. + ·04*
72 W. − ·03*
69 W. + ·06*

p.e. ± ·032

May 28.

57 W. − ·01
105 E. + ·13*
110 E. + ·06
119 E. + ·01
107 E. − ·03
70 W. − ·03
125 E. − ·05
77 W. − ·11*
62 W. − ·01
120 E. + ·01
132 E. + ·03
68 W. − ·05
116 E. − ·01*
72 W. − ·01*
69 W. + ·01*

p.e. ± ·035

June 26.

117 E. − ·01
118 E. + ·03
137 E. + ·03

June 26—*cont.*

74 W. + ·02
88 W. − ·01*
87 W. − ·04
130 E. − ·01
78 W. + ·03
76 W. − ·03
139 E. − ·06
98 W. − ·08
134 E. − ·05
81 W. − ·06

p.e. ± ·028

June 27.

66 W. − ·22*
117 E. + ·03
118 E. + ·03
137 E. − ·08
74 W. − ·04
136 E. + ·01
87 W. + ·02
130 E. − ·01
78 W. + ·02
76 W. − ·01
139 E. + ·11
98 W. + ·22
134 E. + ·13
35 W. + ·04

p.e. ± ·067

June 30.

118 E. − ·02
137 E. + ·07
74 W. + ·02
136 E. − ·02
87 W. ·00
130 E. − ·11
78 W. − ·01

June 30—*cont.*

76 W. + ·04
139 E. − ·02
98 W. − ·07
134 E. + ·02
81 W. + ·01
149 E. − ·01
85 W. − ·05
131 E. − ·02
153 E. − ·03
90 W. − ·01
93 W. − ·04*
143 E. + ·07
p.e. ± ·034

July 1.

80 W. − ·07*
117 E. − ·03
118 E. − ·03
137 E. − ·01
74 W. ·00
136 E. + ·01
88 W. − ·03*
87 W. ·00
130 E. + ·01
78 W. + ·05
76 W. + ·02
139 E. − ·03
98 W − ·05
134 E. − ·03
81 W. + ·02
149 E. + ·03
85 W. + ·03
131 E. ·00
153 E. + ·01
90 W. ·00
93 W. − ·06*
146 E. − ·01
p.e. ± ·021

Aug. 23.

130 E. + ·13
78 W. − ·10
98 W. − ·03
134 E. − ·08
81 W. + ·04
149 E. − ·01
85 W. − ·03
131 E. + 03
153 E. + ·03
90 W. + ·01
86 W. − ·05
143 E. − ·01
127 E. − ·19*
109 W. + ·04*
p.e. ± ·051

Sept. 8.

11 E. + ·01
14 E. + ·04
7 E. − ·09
148 E. − ·06*
13 E. ·00
117 W. − ·06
118 W. − ·06
116 W. + ·02
155 E. + ·09
113 W ·00*
4 E. − ·05
3 E. + ·05
p e. ± ·036

Sept. 16.

105 W. + ·01*
107 W. + ·10*
4 E. − ·06
3 E. − ·01
106 W. − ·06*

Sept. 16—*cont.*

21 E. + ·19*
133 W. − ·02*
17 E. − ·18
120 W. − ·03
124 W. + ·01
p.e. ± ·060

Sept. 18.

13 E. − ·02
99 W. + ·06*
117 W. − ·07
118 W. − ·01
116 W. − ·03
155 E. + ·06
1 E. + ·05
108 W. − ·01*
4 E. + ·14
3 E. − ·05
p.e. ± ·042

Sept. 24.

86 W. + ·07*
143 E. − ·04
127 E. − ·03*
83 W. − ·02*
109 W. − ·02*
105 W. − ·05*
6 E. + ·02*
84 W. − ·08*
112 W. + ·08*
102 W. + ·02
89 W. + ·03*
110 W. + ·01
5 E. − ·04
11 E. + ·04
14 E. + ·03
7 E. + ·07

Sept. 24—*cont.*

148 E. − ·05*
123 W. + ·06*
18 E. + ·06*
104 W. − ·07*
118 W. + ·08
116 W. ·00
155 E. − ·11
p.e. ± ·036

Oct. 8.

95 W. + ·05*
102 W. ·00
152 E. + ·02*
110 W. + ·07
5 E. + ·02
100 W. + ·02*
11 E. − ·09
14 E. − ·07
99 W. − ·10*
p.e. ± ·040

Oct. 11.

84 W. − ·18*
112 W. − ·09*
95 W. − ·01*
102 W. + ·01
110 W − ·09
5 E. + ·02
(100 W. + ·29*)
11 E. + ·02
14 E. ·00
7 E. + ·03
13 E. + ·03
18 E. − ·01*
117 W. + ·12
118 W. + ·07
116 W. − ·07

Oct. 11—*cont.*

155 E. + ·03
1 E. − ·02
p.e. ± ·047
(p.e. ± ·065)

Oct. 20.

8 E. + ·12*
17 E. + ·14
120 W. ·00
124 W. − ·02
138 W. + ·07*
23 E. − ·06*
22 E. − ·01
119 W. − ·03
134 W. + ·11
34 E. − ·02
121 W. − ·02
28 E. − ·08
125 W. − ·10
144 W. + ·11
29 E. + ·07
44 E. − ·01
27 E. + ·06
35 E. − ·08
38 E. − ·02
126 W. − ·04
36 E. − ·08
129 W. − ·05
136 W. − ·03
p.e. ± ·047

Oct. 21.

120 W. + ·01
124 W. + ·02
138 W. + 04*
23 E. − ·01*
22 E + ·06

Oct. 21—*cont.*

119 W. − ·03
134 W. − ·05
34 E. − ·02
121 W. + ·04
28 E. + ·01
141 W. − ·02
125 W. + ·01
p.e. ± ·021

Oct. 30.

22 E. − ·04
119 W. + ·04
134 W. − ·06
34 E. − ·05
121 W. − ·02
141 W. + ·03
125 W. + ·08
144 W. − ·06
148 W. − ·04
44 E. + ·06
27 E. − ·01
35 E. + ·03
38 E. + ·02
126 W. + ·01
36 E. ·00
129 W. − ·02
136 W. + ·01
37 E. + ·04*
p.e. ± ·027

Nov. 1.

118 W. − ·10
116 W. + 06
155 E. − ·09
1 E. − ·02
108 W. + ·01*
4 E. − ·04

Nov. 1—*cont.*

9 E. − ·02*
3 E. ·00
106 W. − ·09*
21 E. + ·11*
19 E. − ·02*
17 E. + ·05
120 W. + ·01
p.e. ± ·040

Nov. 7.

34 E. + ·11
121 W. + ·04
141 W. + ·10
125 W. − ·06
144 W. − ·01
29 E. − ·12
148 W. − ·09
44 E. − ·03
27 E. + ·01
35 E. + ·05
38 E. ·00
126 W. − ·05
36 E. + ·04
129 W. + ·07
136 W. + ·01
p.e. ± ·044

Nov. 10.

121 W. − ·02
28 E. + ·03
141 W. − ·10
125 W. + ·01
144 W. + ·03
29 E. − ·04
148 W. + ·06
44 E. − ·01
27 E. + ·02

Nov. 10—*cont.*

35 E. + ·02
38 E. + ·04
126 W. + ·01
36 E. ·00
129 W. + ·02
136 W. + ·03
p.e. ± ·026

Nov. 12.

121 W. + ·02
28 E. ·00
141 W. ·00
125 W. + ·07
144 W. − ·01
29 E. + ·05
148 W. ·00
44 E. + ·06
27 E. − ·04
35 E. − ·04
38 E. − ·06
p.e ± ·028

Nov. 17.

144 W. − ·07
29 E. + ·03
148 W + ·03
44 E. − ·07
27 E. − ·03
35 E. − ·02
38 E. + ·03
126 W. + ·06
36 E. + ·07
129 W. − ·01
136 W. + ·04
33 E. + ·07
41 E. + ·02
143 W ·00*

Nov. 17—*cont.*	Nov. 21—*cont.*	Dec. 15.	Dec. 15—*cont.*
132 W. − ·05*	141 W. − ·02	23 E. + ·18	35 E. + ·04
52 E. + ·10*	125 W. + ·02	119 W + ·06	38 E. + ·07
139 W. − ·09*	144 W. + ·10	134 W. + ·19	36 E. − ·04
3 W. + ·05*	36 E. − ·03	34 E. − ·03	129 W. + ·09
42 E. − ·01*	129 W. − ·01	121 W. − ·01	136 W. − ·01
4 W. + ·05*	136 W. − ·04	28 E. − ·14	37 E. + ·05
39 E. − ·09*	37 E. + ·09*	141 W. − ·19	26 E. − ·18*
p.e. ± ·037	33 E. − ·02	125 W. − ·12	41 E. − ·05
	41 E. − ·04*	144 W. − ·10	143 W. − ·07
	143 W. − ·04*	29 E. − ·01	p.e. ± ·072
Nov. 21.	132 W. − ·05*	148 W. + ·10	
121 W. − ·05	52 E. + ·07*	27 E. + ·13	
28 E. + ·03	p.e. ± ·034		

Note.—*p.e.* denotes the probable error of a single observation, and is equal to ·6745 × the square root of the mean of the squares of the residuals above it.

On 1902 October 11 the star 100 W. which was observed on only one other occasion gave an anomalous residual; the p.e. is shown excluding this residual, and also (in brackets) including it.

Besides the observations recorded above, a number of sets were discarded in the earlier part of the year. This was because they showed clearly that a single value of z would not accord with them all, and I had not then adopted any method I considered satisfactory for allowing for a change in z. Some sets also were rejected because they were too short to be worth reducing. Under these heads were rejected—on January 18, 13 stars; on January 31, 7 stars; on March 22, 3 stars; on March 25, 19 stars; on March 29, 15 stars; and on April 10, 26 stars, being in each case the whole set observed by one or other observer. In some of these cases all that was wanted was an allowance for a uniform change in z. On the same plan, the observations of June 27, included above, should have either been discarded or else treated for the change in z which they exhibit.

The whole of the above list includes 608 residuals; omitting none, the probable error of a single observation is ±·0402, or in Z.D. ±0″·402; omitting the complete sets of June 27 and December 15, there are 573 stars with a probable error of ±0″·375.

It is clear that this discordance would be materially reduced had the number of stars with one or two observations only played a smaller part. For example, on May 8 the average discordance for stars observed three times and more is ±·022; for the others, ±·050; or, again, compare the sets of January 29, 30 with that of April 2; or, again, note that on July 1 of 22 stars,

the only residuals which exceed 0·05 are those of stars not observed three times.

It is also clear that some of the earlier sets which were not examined for a change in z would be greatly improved had such a change been allowed for. The sets of April 23, April 26, May 2, would be almost reduced to zero by such an allowance; June 27 requires the allowance also; the two sets of April 4 show such a change, but, curiously, in opposite directions; and there are other cases only a little less clearly marked.

If z always changed uniformly with the time, the amount of this change would matter little. For instance, October 21, on which the change in $10z$ was estimated at 2″·07 per hour, gives rather smaller residuals than October 30, when it was estimated at zero. By the method of discussion employed above one state is as safely dealt with as the other. But it is clear from the considerable oscillations in the probable errors of the above sets that there is also an erratic element, and that this erratic element is of very considerable amount, and is sometimes sensibly absent for long periods together. How far this element is observational, or instrumental, or atmospheric, I am not prepared at once to say. In the later months, when the probable error was somewhat greater than in the earlier months, the clock was not going so well, and this may have had some small effect, but would certainly not account for all. A full understanding of this matter is the key to the use of the almucantar; and if it is at present somewhat obscure, it illustrates the essential simplicity of the instrument that we can so soon and so certainly fix attention upon a single requisite.

The average of the first three residuals of each night exceeds that of the last three; they are respectively ·050 and ·041. This can only be due to some observational fault in the way work is begun each night, and ought to disappear in future series.

§ 8. *Observed Residuals, Correcting Star Places.*

The following is a list of the stars observed from 1901 December 27 to 1902 December 15. The places to which these observed residuals are corrections are the places of the *Nautical Almanac* or of the Berlin *Astronomisches Jahrbuch* of 1902, the latter indicated by the letters B.J. The quantities required for deducing the corrections to R.A. and Decl., being the coefficients $1{\cdot}5 \sin t_0 \cos \delta_0$, $\pm \cos t_0$, are given with each star; thus, for example, we have from α *Cephei*, No. 136, taking the means of the recorded quantities

$$\cdot 656\ \Delta\alpha^s - 0{\cdot}351\ \frac{\Delta\delta''}{10} = -0{\cdot}05$$

$$\cdot 656\ \Delta\alpha^s + 0{\cdot}351\ \frac{\Delta\delta''}{10} = -0{\cdot}11$$

or

$$\Delta\alpha = -0^s{\cdot}12,\quad \Delta\delta = -0''{\cdot}86$$

It will be noticed that in most of the following cases I have not got observations both east and west: this arose from the interruptions in the observing which must always beset the first observations of a new instrument. It is not at present my purpose to offer a schedule of corrections to the two catalogues employed. The following list is rather put forward to show how far the different observations of the same star agree with one another at the present stage.

List of Observed Residuals, 1901 *December* 27 *to* 1902 *November* 21.

1. α Androm.

·711 ± ·841.

	E.
1902. Sept.	18 +·02
Oct.	11 −·05
Nov.	1 −·05

2. β Cassiop.

·717 ± ·398.

	W.
1901. Dec.	27 +·01
1902. Jan.	30 −·13

3. ε Androm.

·717 ± ·838.

	E.
1902. Sept.	8 +·08
	16 +·02
	18 −·02
Nov.	1 +·03

	W.
1902. Nov.	17 −·05

4. δ Androm. B.J.

·750 ± ·812.

	E.
1902. Sept.	8 ·00
	16 −·01
	18 +·19
Nov.	1 +·01

	W.
1902. Nov.	17 −·05

5. α Cassiop.

·756 ± ·433.

	E.
1902. Sept.	24 −·02
Oct.	8 +·04
	11 +·04

6. 21 Cassiop. B.J.

·394 ± ·194.

	E.
1902. Sept.	24 +·02

7. ο Cassiop. B.J.

·845 ± ·547.

	E.
1902. Sept.	8 −·11
	24 +·05
Oct.	11 +·01

	W.
1902. Jan.	29 −·08

8. ζ Androm. B.J.

·525 ± ·924.

	E.
1902. Oct.	20 +·12

9. β Androm.

·832 ± ·736.

	E.
1902. Nov.	1 −·02

11. 43 Cassiop. B.J.

·550 ± ·281.

	E.
1902. Sept.	8 +·08
	24 +·11
Oct.	8 −·02
	11 +·09

12. φ Persei, B.J.

·825 ± ·513.

	W.
1902. Jan.	30 −·01

13. ε Cassiop.

·637 ± ·338.

	E.
1902. Sept.	8 −·06
	18 −·08
Oct.	11 −·03

14. 50 Cassiop. B.J.

·453 ± ·225

	E.
1902 Sept.	8 ·00
	24 −·01
Oct.	8 −·11
	11 −·04

15. γ Androm.

·865 ± ·633.

	W.
1901. Dec.	27 −·04

17.
β Trianguli.
·825 ± ·745.

E.
1902
Sept. 16 −·16
Oct. 20 + 16
Nov. 1 +·07

W.
1901.
Dec. 27 +·01

18.
55 Cassiop. B.J.
·581 ± ·300.

E.
1902.
Sept. 24 +·06
Oct. 11 −·01

W.
1902.
Jan. 30 +·07
Feb. 17 −·07

19.
θ Persei, B.J.
·836 ± ·532.

1902.
Nov. 1 −·02

21.
τ Persei, B.J.
·803 ± ·483.

E.
1902.
Sept. 16 +·19
Nov. 1 +·11

W.
1902.
Jan. 30 +·05
31 +·04
Feb. 17 −·06

22.
ρ Persei, B J.
·858 ± ·684.

1902.
Oct. 20 +·02
21 +·09
30 −·01

W.
1902.
Jan. 30 −·05
31 ·00

23.
β Persei.
·864 ± ·652.

E.
1902.
Oct. 20 −·06
21 ·01
(Dec. 15 +·14)

24.
a Persei.
·831 ± ·522.

E.
1901.
Dec. 27 −·06

W.
1902.
Jan. 30 ·00
Apr. 9 −·06

27.
ζ Persei.
·781 ± ·791.

E.
1901.
Dec. 27 +·02
1902.
Oct. 20 +·06
30 −·01
Nov. 7 +·01
10 +·02
12 −·04
17 −·03
(Dec. 15 +·13)

W.
1902.
Jan. 31 ·00

28.
ε Persei.
·862 ± ·664.

E.
1902.
Oct. 20 −·15
21 −·06
Nov. 10 −·04
12 −·07
17 −·04
(Dec. 15 −·21)

29.
ξ Persei, B.J.
·836 ± ·729.

E.
1902.
Oct. 20 +·05
Nov. 7 −·14
10 −·06
12 +·03
17 +·01
(Dec. 15 −·03)

30.
Groomb. 848 B.J.
·363 ± ·177.

W.
1902.
Mar. 17 −·02
22 +·03
Apr. 2 −·03
17 +·01

31.
4 Camel. B.J.
·748 ± ·425.

W.
1902.
Feb. 28 +·06
Mar. 10 +·08
Apr. 17 +·06

33.
ι Aurigæ.
·804 ± ·769.

E.
1901.
Dec. 27 −·09
1902.
Nov. 17 +·03
21 −·06

34.
10 Camel. B.J.
·689 ± ·376.

E.
1902.
Oct. 20 −·09
21 −·09
30 −·12
Nov. 7 +·04
(Dec. 15 −·10)

W.
1902.
Apr. 9 −·09

35.
ϵ Aurigæ, B.J.

·863 ± ·606.

1901. Dec. 27	+ ·10
1902. Oct. 20	− ·02
30	+ ·09
Nov. 7	+ ·11
10	+ ·08
12	+ ·02
17	+ ·04
(Dec. 15	+ ·10)

W.

1902. Feb. 17	+ ·16
28	+ ·10
Mar. 10	− ·01
Apr. 17	+ ·09

36.
η Aurigæ.

·865 ± ·644.

E.

1902. Oct. 20	− ·12
30	− ·04
Nov. 7	·00
10	− ·04
17	+ ·03
21	− ·07
(Dec. 15	− ·08)

W.

1902 Feb. 17	+ ·05
28	− ·03
Apr. 9	+ ·06
17	− ·05

37.
μ Aurigæ, B.J.

·857 ± ·685

E.

1902. Oct. 30	+ ·04
Nov. 21	+ ·09
(Dec. 15	+ ·12)

38.
α Aurigæ.

·855 ± ·574

E.

1901. Dec. 27	− ·04
1902. Oct. 20	− ·04
30	·00
Nov. 7	− ·02
10	+ ·02
12	− ·08
17	+ ·01
(Dec. 15	+ ·05)

W.

1902. Feb. 28	− ·11
Mar. 10	− ·05
Apr. 17	− ·11

39.
β Tauri.

·711 ± ·842

E.

1902. Nov. 17	− ·09

W.

1902. Feb. 17	− ·03

40.
o Aurigæ, B.J.

·828 ± ·519

W.

1902. Mar. 22	+ ·01

41.
β Aurigæ.

·850 ± ·587

E.

1902. Nov. 17	·00
21	− ·04
(Dec. 15	− ·07)

W.

1902. Mar. 22	− ·10

42.
θ Aurigæ.

·850 ± ·703

E.

1902. Nov. 17	− ·01

W.

1902. Feb. 28	·00
Mar. 10	− ·01
Apr. 17	− ·08

43.
1 Gem

·498 ± ·933

W.

1902. Apr. 9	− ·03

44.
22 H. Camel. B.J.

·511 ± ·258

E.

1902. Oct. 20	·00
30	+ ·07
Nov. 7	− ·02
10	·00
12	+ ·07
17	− ·06

W.

1902. Mar. 22	+ ·02
Apr. 2	+ ·01
4	+ ·10
26	+ ·03
May 8	+ ·02

46.
θ Gem. B.J.

·819 ± ·732

E.

1902. Feb. 28	− ·07
Mar. 10	− ·06
17	− ·02
Apr. 9	+ ·01

48.
α_2 Gem.

·790 ± ·783

E.

1901. Dec. 27	+ ·04

W.

1902. Apr. 17	+ ·06

49.
κ Gem. B.J.

·570 ± ·909

E.

1902.		
Jan.	30	+ ·05
	31	− ·07

50.
β Gem.

·705 ± ·846

W.

1902.		
Feb.	28	+ ·03
Mar.	10	+ ·07
	17	+ ·03
	22	+ ·04
Apr.	9	+ ·08

51.
π Gem. B.J.

·814 ± ·758

E.

1902.		
Jan.	29	− ·08

W.

1902.		
Mar.	10	− ·04
	17	− ·06
Apr.	4	− ·10

52.
Groomb. 1374 B.J.

·401 ± ·197

E.

1902.		
Nov.	17	+ ·10
	21	+ ·07

W.

1902.		
May	8	+ ·17

53.
6 Cancri.

·698 ± ·850

E.

1902.		
Jan.	30	+ ·07

W.

1902.		
Mar.	17	+ ·05
Apr.	2	+ ·01

54.
31 Lyncis, B.J.

·863 ± ·608

E.

1902.		
Jan.	30	− ·04

W.

1902.		
Apr.	2	− ·05
	4	− ·07
	23	− ·06
May	1	− ·06
	8	− ·05

55.
o Urs. Maj.

·676 ± ·366

E.

1901.		
Dec.	27	− ·02

W.

1902.		
May	2	+ ·03
	8	− ·03

56.
ι Urs. Maj.

·840 ± ·538

E.

1901.		
Dec.	27	− ·03

W.

1902.		
May	1	·00
	2	+ ·04
	8	+ ·02

57.
σ_2 Urs. Maj. B.J.

·551 ± ·282

W.

1902.		
May	8	− ·14
	20	− ·03
	23	− ·07
	28	− ·07

58.
α Lyncis.

·829 ± ·740

E

1902.		
Jan.	31	+ ·08

W.

1902.		
Apr.	23	+ ·05
May	1	+ ·04
	2	− ·08

59.
θ Urs. Maj.

·805 ± ·486

W.

1902.		
May	1	− ·04
	8	− ·04
	23	− ·01

60.
ε Leonis.

·550 ± ·916

W.

1902.		
Mar.	22	+ ·01
Apr.	2	+ ·04
	4	+ ·05

61.
μ Leonis.

·646 ± ·877

W.

1902.		
Apr.	2	+ ·03
	4	+ ·05
	23	+ ·03
May	1	+ ·04
	8	+ ·08

62.
Groomb. 1586 B.J.

·421 ± ·207

W.

1902.		
May	20	+ ·09
	23	+ ·08
	28	+ ·10

63.
λ Urs. Maj. B.J.

·864 ± ·609

E.
1902.
Jan. 30 −·08
31 +·05

64.
ζ Leonis.

·534 ± ·921

E.
1902.
Apr. 17 −·04

65.
μ Urs. Maj.

·865 ± ·631

W.
1902.
May 8 −·03
23 −·14

66.
9 H. Drac. B.J.

·352 ± ·171

W.
1902.
June 27 +·22

67.
42 Leo Min. B.J.

·773 ± ·798

E.
1902.
Feb. 17 ·00
28 +·08

68.
β Urs. Maj.

·744 ± ·421

E.
1902.
Jan. 31 +·03

W.
1902.
May 20 −·11
23 −·01
28 +·02

69.
α Urs. Maj.

·655 ± ·350

W.
1902.
May 23 −·06
28 −·01

70.
ψ Urs. Maj.

·859 ± ·586

E.
1902.
Jan. 31 −·05

W.
1902.
May 20 −·03
23 −·02
28 +·02

72.
χ Urs. Maj. B.J.

·840 ± ·539

W.
1902.
May 23 +·03
28 +·01

73.
γ Urs. Maj.

·780 ± ·457

E.
1902
Jan. 31 ·00
Feb. 17 −·09

74.
δ Urs. Maj. B.J.

·733 ± ·412

E.
1902.
Feb. 17 −·09

W.
1902.
June 26 −·04
27 +·02
30 −·04
July 1 −·02

75.
8 Can. Ven. B.J.

·865 ± ·632

E.
1902.
Feb. 28 +·06
Mar. 10 ·00
17 +·01
Apr. 9 −·02

76.
76 Urs. Maj. B.J.

·635 ± ·337

E.
1902
Jan. 31 −·05
Feb. 17 −·03

W.
1902.
June 26 +·08
27 +·06
30 +·01
July 1 +·03

77.
31 Comæ.

·698 ± ·850

E.
1902.
Mar. 22 −·06
Apr. 2 +·05
4 ·00
26 −·04

W.
1902.
May 20 +·10
28 +·11

78.
ε Urs. Maj.

·749 ± ·426

E.
1902.
Apr. 17 +·19

W.
1902.
June 26 −·12
27 −·11
30 −·08
July 1 −·14
Aug. 23 +·01

79.
8 Drac. B.J.

·584 ± ·301

E.
1902.
Feb. 28 −·15

80.
α Can. Ven.

·859 ± ·678

E.

1902.	
Feb. 28	+ ·07
Mar. 10	+ ·04
17	− ·05
22	+ ·10
Apr. 9	+ ·11

W.

1902.	
July 1	+ ·07

81.
η Urs. Maj.

·828 ± ·518

E.

1902.	
Apr. 17	− ·08

W.

1902.	
June 26	+ ·03
30	− ·04
July 1	− ·05
Aug. 23	− ·07

82.
11 Boötis, B.J.

·691 ± ·854

E.

1902.	
Apr. 2	− ·05
4	+ ·07
23	− ·03
May 1	+ ·03
8	+ ·02

83.
α Drac.

·605 ± ·316

E.

1902.	
Feb. 28	− ·02
Mar. 10	− ·08
17	·00
22	− ·05
Apr. 9	− ·12

W.

1902.	
Sept. 24	+ ·02

84.
4 Urs. Min. B.J.

·308 ± ·149

E.

1902.	
Feb. 28	+ ·07
Mar. 10	+ ·13

W.

1902.	
Sept. 24	+ ·08
Oct. 11	+ ·18

85.
λ Boötis, B.J.

·852 ± ·565

E.

1902.	
Mar. 17	+ ·09
22	+ ·05
Apr. 4	+ ·04
17	·00
26	− ·01

W.

1902.	
June 27	+ ·02
30	+ ·11
July 1	+ ·03
Aug. 23	+ ·09

86.
θ Boötis, B.J.

·803 ± ·483

E.

1902.	
Mar. 10	·00
17	+ ·01
22	− ·03
Apr. 2	·00
4	+ ·03

W.

1902.	
Aug. 23	+ ·02
Sept. 24	− ·07

87.
ρ Boötis.

·765 ± ·804

W.

1902.	
June 26	·00
27	− ·06
30	− ·04
July 1	− ·04

88.
ϵ_2 Boötis.

·680 ± ·859

E.

1902.	
May 1	− ·02
2	− ·04
8	− ·05

W.

1902.	
June 26	+ ·01
July 1	+ ·03

89.
β Urs. Min.

·392 ± ·192

E.

1902.	
Feb. 28	+ ·06
Mar. 10	·00
Apr. 9	·00

W.

1902.	
Sept. 24	− ·03

90.
β Boötis.

·865 ± ·649

W.

1902.	
June 30	− ·02
July 1	− ·03
Aug. 23	− ·04

92.
δ Boötis.

·814 ± ·758

E.

1902.	
Apr. 2	− ·01
May 1	·00
2	− ·10
8	+ ·02

93.
μ Boötis, B.J.
·853 ± ·695
E.
1902
Apr. 2 + ·11
May 1 + ·08
2 + ·08
W.
1902.
June 30 + ·04
July 1 + ·06

94.
γ Urs. Min.
·448 ± ·222
E.
1902.
Mar. 10 − ·07
17 − ·07
Apr. 2 − ·06
4 − ·01

95.
ι Drac.
·707 ± ·388
W.
1902.
Oct. 8 − ·05
11 + ·01

96.
β Coronæ, B.J.
·734 ± ·827
1902.
May 1 − ·08
8 − ·09

97.
ν Boötis, B.J.
·865 ± ·643
E.
1902.
May 2 + ·02

98.
α Coronæ.
·665 ± ·867
W.
1902.
June 26 + ·05
27 − ·25
30 + ·04
July 1 + ·02
Aug. 23 ·00

99.
ζ Urs. Min.
·306 ± ·148
E.
1902.
Mar. 22 − ·09
Apr. 2 + ·03
„ 17 − ·14
W.
1902.
Sept. 18 − ·06
Oct. 8 + ·10

100.
θ Dra. B.J.
·713 ± ·395
E.
1902.
Apr. 2 − ·15
4 − ·12
23 − ·07
26 − ·07
May 1 − ·19
8 − ·10
W.
1902.
Oct. 8 − ·02
11 − ·29

101.
19 Urs. Min. B.J.
356 ± ·173
E.
1902.
Mar. 22 + ·08
Apr. 2 + ·01
4 − ·06
17 + ·06
26 + ·02

102.
τ Herc.
·852 ± ·564
E.
1902.
May 1 + ·16
2 + ·04
8 + ·09
W.
1902.
Sept. 24 + ·16
Oct. 8 + ·18
11 + ·19

104.
A Drac. B.J.
·519 ± ·262
E.
1902.
Apr. 2 + ·06
4 + ·08
23 + ·13
26 + ·10
May 8 + ·08
W.
1902.
Sept. 24 + ·07

105.
ζ Herc.
·784 ± ·789
E.
1902.
May 8 + ·05
28 + ·13
W.
1902.
Sept. 16 − ·01
24 + ·05

106.
ε Urs. Min.
·202 ± ·097
E.
1902.
Apr. 26 + ·03
May 8 − ·01
W.
1902.
Sept. 16 + ·06
Nov. 1 + ·09

107.
ε Herc.
·771 ± ·800
E.
1902.
May 20 + 04
23 + ·03
28 − ·01
W.
1902.
Sept. 16 − ·10

108.
ζ Drac.

·585· ± ·303

W.

1902.		
Sept.	18	+ ·01
Nov.	1	− ·01

109.
δ Herc.

·585 ± ·904

W.

1902.		
Aug.	23	− ·04
Sept.	24	+ ·02

110.
π Herc.

·848 ± ·708

E.

1902.		
May	8	+ ·09
	20	+ ·03
	23	− ·02
	28	+ ·11

W.

1902.		
Sept.	24	·00
Oct.	8	− ·06
	11	+ ·10

111.
β Drac.

·803 ± ·483

E.

1902.		
May	1	+ ·02
	8	·02

112.
89 Herc.

·631 ± ·884

W.

1902.		
Sept.	24	− ·08
Oct.	11	+ ·09

113.
γ Drac.

·812 ± ·494

E.

1902.		
May	8	− ·01
	23	− ·01

W.

1902.		
Sept.	8	·00

115.
χ Drac. B.J.

·437 ± ·216

E.

1902.		
May	1	− ·01
	8	− ·04

116.
α Lyræ.

·858 ± ·681

E.

1902.		
May	23	+ ·04
	28	− ·01

W.

1902.		
Sept.	8	− ·08
	18	− ·03
	24	− ·06
Oct.	11	+ ·01
Nov.	1	− ·12

117.
β Lyræ.

·808 ± ·765

E.

1902.		
June	26	·00
	27	+ ·04
July	1	− ·02

W.

1902.		
Sept.	8	+ ·02
	18	+ ·03
Oct.	11	− ·16

118.
γ Lyræ, B.J.

·798 ± ·776

E.

1902.		
June	26	+ ·05
	27	+ ·05
	30	·00
July	1	− ·01

W.

1902.		
Sept.	8	+ ·07
	18	+ ·02
	24	− ·07
Oct.	11	− ·06
Nov.	1	+ ·11

119.
8 Drac.

·551 ± ·282

E.

1902.		
May	8	− ·01
	23	− ·09
	28	− ·04

W.

1901.		
Dec.	27	− ·04
1902.		
Oct.	20	·00
	21	·00
	30	− ·07
(Dec.	15	− ·09)

120.
κ Cygni, B.J.

793 ± ·472.

E.

1902.		
May	20	− ·03
	23	+ ·05
	28	+ ·03

W.

1902.		
Sept.	16	+ ·01
Oct.	20	− ·02
	21	− ·03
Nov.	1	− ·03

121.
τ Drac. B.J.

·425 ± ·210

W.

1902		
Oct.	20	+ ·02
	21	− ·04
	30	+ ·02

Nov. 7	−·04
10	+·02
12	−·02
21	+·05
(Dec. 15	+·01)

123.
α Vulpec.

562 ± ·913

W.
1902.
Sept. 24 −·06

124.
θ Cygni, B.J.

·827 ± ·515

W.
1902
Sept. 16 +·04
Oct. 20 +·07
21 +·03

125.
ε Drac. B.J.

·497 ± ·250

E.
1902.
May 20 +·01
23 +·06
28 −·04

W.
1902.
Oct. 20 +·20
21 +·09
30 +·02
Nov. 7 +·16
10 +·09
12 +·03
21 +·08
(Dec. 15 +·22)

126.
κ Cygni, B.J.

·323 ± ·156

W.
1902.
Oct. 20 +·15
30 +·10
Nov. 7 +·16
10 +·10
17 +·05

127.
24 Vulpec. B.J.

·558 ± ·913

E.
1902.
Aug. 23 −·19
Sept. 24 −·03

128.
γ Cygni.

·863 ± ·661

W.
1901.
Dec. 27 ·00

129.
73 Drac. B.J.

·390 ± ·192

W.
1902.
Oct. 20 +·06
30 +·03
Nov. 7 −·06
10 −·01
17 +·02
21 +·02
(Dec. 15 −·08)

130.
α Cygni.

·860 ± ·587

E.
1902.
June 26 −·02
27 −·02
30 −·12
July 1 ·00
Aug. 23 +·12

W.
1901.
Dec. 27 +·04

131.
ε Cygni.

·813 ± ·759

E.
1902.
June 30 +·02
July 1 +·04
Aug. 23 +·07

132.
76 Drac. B.J.

·203 ± ·097

E.
1902.
May 20 −·04
23 −·03
28 +·01

W.
1902.
Nov. 17 +·05
21 +·05

133.
32 Vulpec.

·686 ± ·857

W.
1902.
Sept. 16 +·02

134.
γ Cygni, B.J.

·865 ± ·649

E.
1902.
June 26 −·02
27 +·16
30 +·05
July 1 ·00
Aug. 23 −·05

W.
1902.
Oct. 20 −·12
21 +·04
30 +·05
(Dec. 15 −·20)

136.
α Cephei.

·656 ± ·351

E.
1902.
June 27 −·04
30 −·07
July 1 −·04

W.
1902.
Oct. 20 −·08
30 −·12
Nov. 7 −·12
10 −·14
17 −·15
21 −·07
(Dec. 15 −·10)

137.
β Cephei.

·494 ± ·248

1902.
June 26 −·01
27 −·12
30 +·03
July 1 −·05

138.
16 Pegasi.

·607 ± ·894

W.
1902.
Oct. 20 −·07
21 −·04

139.
20 Cephei, B.J.

654 ± ·349

E.
1902.
June 26 −·04
27 +·13
30 ·00
July 1 −·01

W.
1902.
Nov. 17 +·09

140.
ι Pegasi.

·582 ± ·904

W.
1901.
Dec. 27 +·01

141.
π Pegasi B.J.

·800 ± ·774

W.
1902.
Oct. 21 −·07
30 −·12
Nov. 7 −·19
10 +·01
12 −·09
21 −·07
(Dec. 15 +·10)

143.
7 Lacertæ, B.J.

·828 ± ·519

E.
1902.
June 30 +·12
July 1 +·04
Aug. 23 +·04
Sept. 24 +·01

W.
1902.
Nov. 17 ·00
21 +·04
(Dec. 15 +·09)

144.
η Pegasi.

·741 ± ·822

W.
1901.
Dec. 27 +·10
1902.
Oct. 20 −·09
30 +·08
Nov. 7 +·03
10 −·01
12 +·03
Nov. 17 +·09
21 −·08
(Dec. 15 +·12)

146.
μ Pegasi.

·543 ± ·918

W.
1901.
Dec. 27 −13

147.
ι Cephei, B.J.

·588 ± ·305
1902.
Jan. 29 +·13

148.
β Pegasi, B.J.

·682 ± ·858

E.
1902.
Sept. 8 −·06
24 −·05

W.
1901.
Dec. 27 −·01
1902.
Oct. 30 +·05
Nov. 7 +·10
10 −·05
12 +·01
17 −·02
(Dec. 15 −·09)

149.
π Cephei, B.J.

·384 ± ·189

1902.
June 30 −·03
July 1 +·01
Aug. 23 −·03

150.
Br. 3077 B.J.

·748 ± ·425

1902.
Jan. 29 +·11

152.
ι Androm. B.J.
·865 ± ·619
1902.
Oct. 8 +·02

153.
γ Cephei.

·331 ± ·160

1902.
June 30 −·02
July 1 +·02
Aug. 23 +·04

W.
1901.
Dec. 27 −·03

155.
μ Androm.

·855 ± ·691

1902.
Sept. 8 +·09
18 +·06
24 −·11
Oct. 11 +·03
Nov. 1 −·09

W
1902.
Dec. 27 +·04

§ 9. *Conclusion.*

In putting forward these observations I am regretfully aware of their incompleteness. I propose to continue the research with the intention of (i) examining the origin in the hourly changes in z, with a view to their reduction or removal, (ii) finding the latitude, (iii) investigating difference of personality of two observers in different oblique transits, and (iv) forming a catalogue of star places and discovering what, if any, are the systematic differences of places found by the transit circle and almucantar. I do not wish hastily to express an opinion on the merits of the instrument beyond what the foregoing results will evidence, and will only say that in the cases of difficulty that have already arisen I have found it so tractable that I look with considerable confidence to reducing or removing the small anomalies that remain.